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MEASUREMENT AND VERIFICATION OF BUILDING PERFORMANCE CHARACTERISTICS

FEBRUARY 2008

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NATIONAL CENTER FOR ENERGY MANAGEMENT AND BUILDING TECHNOLOGIES
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EXECUTIVE SUMMARY

Building performance characteristics influence energy usage and environmental conditions in indoor environments. Therefore, building owners and managers, architects, industry, and regulatory agencies are focusing on design, construction, maintenance, and remediation solutions for buildings and building systems to improve energy efficiency and alleviate indoor environmental quality (IEQ) concerns. However, substantial gaps in knowledge remain and there have been scientific/engineering limitations to resolving these issues. The lack of integrated building protocols and normative baseline data to assess the relationships of building performance and energy consumption contribute to problems in solving IEQ and other building performance concerns. This task was designed to develop protocols for the measurement of integrated building performance and to measure selected environmental parameters in selected buildings throughout the United States. A series of hypotheses were developed and challenged, and an occupant questionnaire was developed to verify or refute the underlying hypotheses.

A literature search was conducted to obtain information on the status of relevant research for this task and to assist in the selection of measurement methods. Information from the literature search supported the premise that there are gaps in knowledge in the field of IEQ and monitoring indoor environments. Recognizing the lack of established protocols for assessing buildings prompted the development of a suite of measurement protocols to assess IEQ parameters including thermal comfort (i.e., temperature, relative humidity, and draft), carbon dioxide (CO_2), surface, and airborne mold, and volatile organic compounds (VOCs) in office buildings. Protocols to assess lighting and acoustics were also included as these are critical to a total quality of the indoor environment, occupant satisfaction and they impact energy usage. Protocols for documenting energy usage and building operational performance were also developed, and selection criteria for buildings to participate in the study were integrated in the study design. This study was tasked to provide data on the selected parameters across ten office buildings in the United States and to correlate those data with responses of building occupants to a computer-based questionnaire focused on their perception of their indoor work environment.

Ten office buildings were selected based on building design and construction characteristics as determined by a series of screening questions answered by the buildings' facilities department personnel. This information included the physical characteristics of the building, the age of the structure, its geographical location, and the type of mechanical air handling system. Critical to building participation was concern expressed by building management/owners that a costly response would be necessary to renovate or retrofit their building if poor IEQ or other parameters were evident during the monitoring. Additionally, there were concerns that the monitoring process itself would place undue hardships on the work flow of the offices in the building.

A computer-based occupant perception questionnaire was developed to obtain information from the building occupants regarding their perception of IEQ, lighting, and sound in their workspace and to obtain sufficient data to verify or refute the underlying hypotheses of the measurements.

In each building, the indoor office area available for participation in the study was divided into six zones/locations. An attempt was made to make these zones representative of natural divisions within a building (e.g., floor, interior areas, perimeter areas, private offices, open offices). Measurement instrumentation was located in each of the six indoor zones. Additionally, an outdoor location was selected to obtain specific IEQ measurements. Details on the placement and types of instrumentation are listed in the Methods section of this report.

Based on average values of temperature and humidity, only 6 of the 10 buildings were within the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) measurement criteria for thermal acceptability. However, thermal comfort (temperature and humidity) was perceived as acceptable by a majority of building occupant respondents in all ten of the buildings. There was limited

inter-zone variability in the perception of thermal comfort, which was not consistently related to variables (e.g., frequency of air conditioning, heating, or ability to control or know the value of the temperature). None of the buildings had both measured conditions and occupant responses to thermal comfort that met the ASHRAE thermal comfort criteria. Also, in all but two buildings the questionnaire participation rates were so low that they cannot be considered representative of the entire building population. In the two buildings with low questionnaire response, acceptability approached 80%. However, these buildings did not meet the winter ASHRAE temperature criteria. Those two buildings also had the overall highest workplace environment acceptability ratings, which may or may not have biased the responses to thermal acceptability. Temperature fluctuation between the morning and the afternoon was not problematic in the buildings monitored. Occupant perception of temperature acceptability correlated with the minimal actual temperature fluctuation in only two buildings, one of which had significant inter-zone variability among respondents. The lack of consistent correlation was likely due to the relatively low number and percentage of occupants in each building who perceive a temperature fluctuation problem. In most buildings where occupants could adjust the temperature themselves via a thermostat, <10% did so in response to temperatures being too cool. The proportion approached 10% in response to being too warm. The average vertical temp gradient for all ten buildings was <3.0°C. The vertical temperature gradients were within the acceptable level in all buildings and thermal acceptability was not associated with perception of thermal discomfort in a particular body part. All but two of the buildings were within the target humidity range. Inter-zone variability in making adjustments to humidity was limited to one building, which had a mean humidity below the target range. Most buildings had an average draft rate that was <15%. The outdoor-indoor CO_2 difference was within the ASHRAE range for all but two of the buildings, but there was significant inter-zone variability in perception responses for five of the buildings. The CO_2 concentrations did not consistently correlate with occupant responses to questions regarding acceptability of workplace, air freshness or impact on work productivity. Few occupants of the office buildings monitored had negative opinions as to the acceptability of odors in their workplace. VOC data were problematic. The VOC sensors selected and used for this study only permitted measurements of short duration at each location and only measurements of total VOCs were collected. Total VOC measurements were below the limit of detection at all locations.

Low concentrations of airborne culturable and total fungi were present in the ten typical office buildings during the monitoring period. No statistically significant differences were noted in airborne mold by sampling day, indicating that a single sampling period for airborne fungi in non-water damaged buildings is sufficient. Similarly, no statistically significant differences in airborne mold were noted by zones, indicating that a limited number of sampling sites is sufficient to determine the airborne fungal poulations in non-water damaged buildings. Common airborne fungi were noted and airborne culturable *Cladosporium* and *Penicillium* were isolated from 100% of the buildings sampled using the Andersen sampler. Airborne fungi associated with water intrusion/water damage were rarely present in the buildings. Airborne culturable *Chaetomium and Stachybotrys* were never isolated, *Trichoderma* was isolated in only one building and *Aspergillus flavus* was isolated in only two of the buildings. Airborne *Aureobasidium, Stachybotrys,* and *Trichoderma* spores were not observed in any of the 10 buildings with the Burkard sampler, and *Chaetomium* was only found in one sample from one building. Surface-associated *Stachybotrys* was isolated in 15 of the 180 vacuum dust samples (8%), but the concentrations in the majority of the positive samples were at or near the lower limit of detection. No locations were positive for culturable *Stachybotrys* in vacuum dust on more than one of the three sampling days at any of the buildings.

The results of acoustic testing in the ten buildings did not reveal any consistent correlation with measured sound levels within buildings and occupant responses relating to sound existence, annoyance and effect on productivity. Thus, it was not shown that sound levels measured in a zone can be a good predictor of occupant perception of sound and its effect on performance. There can be several reasons for the inability to identify correlation. One is that there is no relationship between measured sound levels and occupant

perception of the effects of sound. However, it is well documented in published literature that occupants are annoyed by high sound levels and such levels do affect productivity. It is possible that the sound levels in the ten buildings did not reach a sufficient difference between zones for occupants' perception to be sensitive to the differences. In that case, the lack of correlation was due to low variation between zones. This is likely as none of the buildings were observed to consistently have sound at levels considered to objectionably outside the normal range for office buildings. In particular, within a building for nearly all cases measured differences between zones in significant sound levels (L_5 to L_90) were less than 6 dB. The 6 dB value is considered noticeable, but may not normally be perceived as a large difference. However if a 6 dB or greater consistent difference actually existed between the zones, that could result in significant differences in occupants' perceptions between those zones. The limited variation in the measured levels cannot be considered the only cause of the inability to identify correlation. It is possible that other levels would have correlated with the perception questionnaire results. However, the sound levels used in this study were based on engineering experience and judgment, and other levels were not collected. A comparison of sound data between buildings suggest that buildings have similar variation in sound levels from one zone measurement station to the next, but also have significant differences in average sound levels. Respondent data from different buildings also show noticeable differences, but the question remains whether the differences correlate.

The ANSI/ASHARE/IESNA standard for lighting recommends 10.76 W/m^2 (1.0 W/ft^2) for office spaces. The average lighting power density (LDP) for the ten office buildings overall was 12.71 W/m^2 (1.18 W/ft^2), 18% over the recommended value. Six of the buildings that used direct lightining systems had 14.27 W/m^2 (1.33 W/ft^2) and the four buildings that used direct/indirect systems had 10.37 W/m^2 (0.96 W/ft^2). One building had very low LPD, only 6.89 W/m^2 (0.64 W/ft^2), because this building uses a great deal of daylight. The overall illuminance at work surfaces of the ten buildings was 657 Lux (± 243 Lux). The design guide recommends 300 to 500 Lux for office lighting, depending on the characteristics of visual tasks. The measured illuminance in the monitored buildings was greater than the maximum of this design range. The four buildings that utilized direct/indirect lighting systems had lower average illuminance at the work surface than the other buildings, which used direct lighting systems. The IESNA lighting handbook lists the uniformity of light distribution on task plane as one of the important design criteria. Most of buildings monitored had uniform lighting distribution at work surface and the four buildings with direct/indirect lighting systems had more uniform light distribution and lower variations. The uniformity of illuminance at the work surface was computed by averaging the ratio of the maximum illuminance to the average illuminance at work surface. Uniformity less than 3.0 is generally considered as uniform. The overall uniformity was 1.91 (±1.15), indicating that most of the buildings had uniform lighting distribution at work surface. The four buildings with direct/indirect lighting systems had more uniform light distribution and lower variations. The illuminance at the center of computer monitor screens was close to the vertical illuminance in offices. The vertical illuminance is considered a very important design criterion in offices, and the recommendation value is 500 Lux. The average measured illuminance at the screens was 339 Lux, which was lower than the recommendation value. The average illuminance at VDT source documents and keyboards were 574 Lux and 525 Lux, respectively. Luminance at partitions or walls and at darkest partitions or walls in the field of view was measured. This parameter was significantly affected by the color of partitions and the influence of daylight. The average luminance at partitions was 49 candela per square meter (cd/m^2) ± 45 cd/m^2. The luminance at darkest partitions or walls in field of view was 16 cd/m^2 ± 45 cd/m^2. Daylight was observed to have influence on a large number of workstations in one of the buildings, resulting in large variations in partition luminance. Luminance at nearby buildings and at brightest sky from windows greatly depended on the weather, window orientation and measurement time. Lighting measured at the work surface for all the buildings demonstrated that the average correlated color temperature (CCT) was 3387 K, which is considered as slightly warm in color. The average color rendering index (CRI) was 81, which is considered as fair color rendering. The Illuminating Engineering Society of North America **(**IESNA) recommends using lamps

with CRI of 70 or greater in offices, or 85 CRI or above if color critical tasks are being performed. No color critical tasks were performed in any office buildings monitored. Therefore, color rendering capabilities of the lighting in these offices should be appropriate.

This study resulted in the development of integrated building protocols and normative baseline data to assess the relationships of building performance and energy consumption, and contributes to solving problems in IEQ and other building performance concerns. The monitoring was completed for ten buildings across the United States and the measurements of selected environmental parameters are available in the NCEMBT Building Sciences Database (www.ncembt.org).

1. LITERATURE REVIEW

1.1 THERMAL COMFORT/INDOOR ENVIRONMENTAL QUALITY

Previous research projects involving the study of thermal comfort in office buildings have utilized questionnaires. The Center for the Built Environment (CBE) and the American Society of Heating, Refrigeration, and Air-conditioning Engineers (ASHRAE) questionnaires (**Appendix A**) were reviewed. Previous research projects focused on performing their engineering studies by sampling the local work station of participants in the survey for a relatively brief time i.e. 10-20 minutes. An ASHRAE-sponsored thermal comfort study surveyed a large number of occupants of several buildings in the San Francisco area (Schiller et al., 1988). In general, occupants' perceptions were closely related to the acceptable levels of thermal comfort as defined by engineering data within ASHRAE standard 55-81. More recently, ASHRAE commissioned a study of thermal comfort in cold climates (Donnini et al., 1999). Occupants of 12 air-conditioned buildings were surveyed; about 15% of the occupants had thermal dissatisfaction. ASHRAE standard 55-81 allows a maximum of 10% thermal dissatisfaction.

Another ASHRAE-sponsored study surveyed occupants (n=836) of 12 air-conditioned buildings in Townsville, Australia (deDear et al., 1994). It found the thermal discomfort perception of occupants was related to the need for a higher air velocity around their air-conditioned work spaces. An ASHRAE-sponsored study surveyed occupants (n=935) of 22 mechanically ventilated buildings in Kalgoorlie-Boulder, Australia, a hot and arid climate (deDear, 1999). During summer months, about 65% of indoor measurements were within the ASHRAE standard 55, while about 85% of indoor measurements were within the standard during winter. The study also found that 86% of occupants considered their thermal conditions acceptable.

Other similar studies have been performed in other locations worldwide. A study was performed in residential buildings in Harbin, China in winter (Wanget al., 2003). It was found that about 92% of occupants felt their thermal environment is acceptable. Over 80% of these occupants felt dry at a relative humidity of 20-30% and over 40% felt dry at a relative humidity of 30-55%. Tham and Ullah (1993) examined thermal comfort in the humid climate of Singapore. In this study, a computer simulation using DOE2.1B software was used to evaluate the variations of envelope design on energy performance and thermal comfort. An equation designed by Fanger (1970) was used to evaluate the expected levels of thermal comfort of the occupants. By considering the variations of the envelope designs, the predicted percentage of dissatisfied occupants varied about 1% between the extremes. A study of office buildings conducted by Chan et al., in Hong Kong (1998) raised concern about the validity of the traditional ASHRAE standard thermal comfort criteria in the field. Jitkhajornwanich et al., (1998) studied transitional spaces in Bangkok. Results indicated in several cases that occupants preferred cooler environments, although some of these transitional spaces were mechanically ventilated.

Demokritou et al., (2002) combined experimental and computational fluid dynamics (CFD) studies to evaluate occupants' comfort in elderly housing in the Boston area. High vertical air temperature differences (above 6°C) were found which created thermal discomfort for the majority of the occupants. It was also found that excessive air change rates and the location of the heating equipment were factors in adding to the thermal discomfort. The CFD approach proved to be a very effective tool for predicting some of these thermal comfort conditions related to the buildings studied. A questionnaire was also administered to building occupants.

Various indices, derived by Fenger (1970), have been calculated from these studies, including predicted percent dissatisfied (PPD), predicted mean vote (PMV) and draft rate (DR). These indices estimate the percent of dissatisfaction by calculating from these predicted indices using some of the engineering data obtained from collection sites and comparing it with actual percentages obtained by evaluating the

outcome from the administered questionnaire. The basis for these thermal comfort evaluations come from ASHRAE standard 55 whose different versions were used (Chan, deDear, Stephen 1998; deDear et al., 1994; deDear 1999; Demokritou et al., 2002; Donnini et al., 1999; Jitkhajornwanich et al., 1998; Schiller et al., 1988; Tham and Ullah 1993; Wang et al., 2003).

1.2 Airborne And Surface-Associated Mold

In the 1980s and early 1990s most of indoor air quality research focused on measuring and implicating chemical contaminants (e.g., formaldehyde and volatile organic compounds), sources from building materials and furnishings in occupied spaces (e.g., new carpeting, construction plywood, asbestos) and general air quality parameters (e.g., carbon dioxide levels, total volatile organic compounds, environmental tobacco smoke) (Batterman and Ping 1995; Gold 1992; Main and Hogan 1983). Ninety-five percent of problems were associated with inadequate ventilation, entrainment of outdoor contaminants, or building furnishings (Seitz 1989). However, it is increasingly evident that microorganisms in the indoor environment, especially fungi, have a significant role in causing human health disorders and resultant disability, as well as contributing to unacceptable air quality in the workplace (Flannigan and Morey 1996; Yang and Johanning 1997). It has been reported that 35-50% of indoor air quality complaints are probably microbial in origin (Lewis 1995) and fungal contamination was found in 12% of buildings investigated in Minnesota during a six-year period (Ellringer et al., 2000). The cost resulting from microbial contaminants in indoor environments has not been adequately investigated, but a recent report estimated that airborne Rhinovirus alone results in an annual cost of $70 billion due to respiratory infections, allergies, and asthma (Russell et al., 2002).

Outdoor air serves as a source of microbial contamination indoors, entering buildings through mechanical air conditioning systems and through open doors and windows (Lighthart and Stetzenbach 1994; Shelton et al., 2002). Mechanical systems (Bernstein et al., 1983; Burkhart et al., 1993; Foarde et al 1997), and heating system humidifiers (Fink et al., 1971) serve as reservoirs of contamination and become a means for dispersal of biocontaminants throughout a building (Sterling 1982). Components of mechanical systems may become contaminated in areas of high moisture near cooling coils and drain/condensation pans and lines (Foarde et al., 1997) and as a result of condensation (Pasanen et al., 1993). Condensation in duct systems can occur when humid air lingers in the duct when the system is turned off (e.g., when the building is not occupied) (Pasanen et al., 2000b). Installation of HVAC components is also important and improper installation of humidification systems or improper sizing of air conditioning units can result in excess moisture (Garrison et al., 1993). Materials that absorb and retain moisture from condensation (e.g., duct materials) and high humidity (e.g., air filters) can readily become contaminated (Elixmann et al., 1987; Kemp et al., 1995a, 1995b; Levetin et al., 2001; Martikainen et al., 1990; Pasansen et al., 1992, 1993, 2000a, 2000b; Simmons and Crow 1995). Filters that are composed of cellulose mixed with polyester fiber on a cardboard frame can serve as nutrient sources (Simmons and Crow 1995), but not all filter material will support microbial growth in the absence of trapped dust and debris (Maus et al., 1996).

Building materials (e.g., wallboard, ceiling tiles, painted surfaces) and furnishings (e.g., wallpaper, carpeting and vinyl flooring, upholstery) can also serve as sites for microbial colonization (Hyvarinen et al., 2001a, b, and c; Shelton et al., 2002, Stetzenbach 2002a). Interior construction in commercial building primarily involves the use of gypsum wallboard and cellulose-based ceiling tiles, but ceiling tiles (Górny et al., 2001) and the paper sides of wallboard (Pasansen et al., 2000a and 2000b) have been shown to serve as a nutritional source for fungal contaminants. Lubricant oils on fiberglass and galvanized steel ducting may contain nutrients for fungal growth (Hyvarinen et al., 2002a, 2002b, and 2002c).

Insulation of wall cavities and ceiling plenums and fibrous flooring materials provide thermal and acoustical benefit in buildings, and wall coverings enhance the visual context of indoor environments. However, if these materials are composed of cellulose (e.g., blown cellulose insulation or paper wall

coverings) they may also serve as a nutritional source for microbial contaminants. Even if these materials are not a source of nutrition, they may trap moisture and organic debris within cavity spaces, thereby providing a suitable environment for the proliferation of microorganisms (Chang et al., 1996). Thermal-bridging and the use of non-porous wall coverings acting as air retarders increase the likelihood of fungal growth on interior surfaces. Additionally, water intrusion resulting from plumbing and roof leaks, flooding, and condensation may provide conditions favorable for microbial growth in buildings (Stetzenbach 2002a).

Moisture may accumulate in floor materials in below grade areas and floors above crawlspaces (Beguin and Nolard 1996). Placement of gypsum wallboard on masonry subfloor can lead to the transport of moisture as wicking of moisture in basements increases moisture in lower floors of buildings (Lawson et al., 1998). Capillary barriers are needed to prevent wicking; amendments to traditional gypsum products (e.g., the addition of wax to prevent moisture accumulation) have been suggested (Ellringer et al., 2000). Relative humidity can affect the growth of fungi on insulation materials (Ezeonu et al., 1994; Pasanen et al., 2000b), but common problems with construction defects that result in accumulation of moisture in wall cavities, plenum spaces, and other areas of a building can also contribute to biocontamination in indoor environments (Miller et al., 2000). Catastrophic events (e.g., floods, strong winds and hurricanes, earthquakes, and fires) also result in water-damage to buildings and building systems (Morey 1993).

In the absence of construction defect and catastrophic events, maintenance practices are important in minimizing microbial contamination (Foarde et al., 1997; Garrison et al., 1993). Failures of caulking and joints, and the lack of maintenance of drain pans and sump pumps can result in the proliferation of biocontaminants (Miller et al., 2000). Floor coverings can serve as sources and reservoirs of microbial contamination, especially when poorly maintained. Fungal contaminants accumulate in settled dust in flooring systems and may proliferate if adequate moisture is available (Beguin and Nolard 1996; Hodgson and Scott 1999). Moisture requirements for colonization and growth of biocontaminants vary. Some xerophilic fungi that grow under conditions of low availability of water, are capable of growth at 60-75% relative humidity (Pasansen et al., 1991; Hyvarinen et al., 2002a, 2002b, and 2002c), while others are organized into groups based on their water activity (availability of water) requirements (Grant et al., 1989; Pasanen et al., 1991). *Penicillium*, a primary colonizer that proliferates with relatively low water activity (Grant et al., 1989; Pasanen et al., 1991), was isolated in over 80% of bulk samples collected from water-damaged wallboard following incubation in humidity chambers (Pasanen et al., 1991). *Aspergillus*, *Cladosporium*, *Stachybotrys*, and *Trichoderma* were also isolated demonstrating the ability of these fungi to colonize and proliferate in the indoor environment. Fluctuating temperatures and humidity moderate the growth of fungi (Pasanen et al., 1991), but because many fungi have the ability to proliferate at low humidity, relative humidity is not a limiting factor for fungal contamination indoors (Hyvarinen et al., 2002a, 2002b, and 2002c).

Once moisture has accumulated on building surfaces, biocontaminants may proliferate and be dispersed as bioaerosols. Air flowing over contaminated building materials (Górny et al., 2001) and air handling duct materials (Buttner et al., 1999; Górny et al., 2001) release biocontaminats to the indoor air. The organisms present in settled dust are also readily dispersed into the indoor air (Buttner et al., 2002a) and this release from surfaces is accomplished with normal human activity such as vacuuming and walking on contaminated flooring materials (Buttner and Stetzenbach 1993).

Unlike chemical contaminants, biocontaminants are particulate, not gaseous; they do not reach equilibrium in indoor environments; and they have temporal and spatial variations in fungal concentration and populations (Hyvarien et al., 2001c). Therefore, determining the concentration and populations of biocontaminants in indoor environments is challenging. Monitoring for microbial contaminants requires methods that will result in accurate, precise, and representative data (Schmechel et al., 2002). Guidance documents have been published (ACGIH 1999; AIHA 1996; NYC 2000, USEPA 2001) outlining sampling and analysis procedures for investigation of indoor environments. These documents and

researchers (Buttner et al., 1997a, 2002b; Jensen et al., 1994; Griffiths et al., 1997; Henningson and Ahlberg 1994; Nevalainen et al., 1992) agree that no one method has been established as a standard for assessing indoor environments, but that several methods are commonly used to estimate the concentration of airborne and surface-associated biocontaminants.

Traditional estimations of fungal contamination rely on the analysis of airborne and surface-associated organisms by culture on artificial growth media or microscopic assay (Burge et al., 1977; Buttner et al., 1997a and 2002b; Chatigny et al., 1989; Flannigan 1997; Samson and Hoekstra 1994). Air sampling is used to determine the presence of airborne fungal spores and characterize exposure to building occupants (Miller et al., 2000). Culture methods for fungal monitoring require typical morphological characteristics of colonies on laboratory media and recognition of microscopic structures. However, fungi that are either overgrown by rapid colonizers, require amendments to classical growth media, or fail to produce typical structures are not detected. Viable methods underestimate concentrations because only culturable spores are enumerated and identified yet non-culturable organisms can elicit adverse reactions by exposed populations. Organisms that are difficult to culture due to nutrient requirements (e.g., xerophilic fungi such as *Wallemia* and *Eurotium*) or elevated temperature (e.g. thermophiles such as *Aspergillus fumigatus* and *Mycopolyspora faeni*) are often not isolated because of a limited scope of work for the investigation. Direct count methods using microscopic assay provide information on the presence of fungal spores and growth structures, but are unable to distinguish some fungal spores at the genus level (e.g., *Aspergillus* and *Penicillium* are enumerated together as a group) and cannot differentiate species within recognizable genera. Processing time for direct counts is highly variable, depending on the level of debris adhering to the test sample surface, the density of the fungal spore deposition, and the efficiency of the analyst.

Despite the current limitations of analysis methods, collection of air and surface samples in the selected office buildings provide a means to evaluate the microbial component of indoor environmental quality (IEQ). When poor IEQ is the result of a microbial contamination problem, facilities management decisions are made that involve costly increases in ventilation and/or repair of HVAC units and ducting. In contrast, well-designed, well-built, and well-maintained buildings would provide indoor environments free of microbial contaminantion and could minimize operation costs. Therefore airborne and surface-associated mold were included in this project to provide data on the presence of these organisms in non-problem office buildings. The methods for the microbial sampling and analysis were selected from the commercially-available instrumentation and analytical support laboratories and this information is presented in the Methods section of this report. Rationale for selection of the instrumentation is presented below.

The Andersen single-stage impactor sampler (Graseby Andersen, Atlanta, GA) is a commonly used device for monitoring airborne culturable microorganisms in indoor environments (Buttner et al., 1997a and 2002b). This device requires electrical power and positive-hole correction is needed to avoid bias due to multiple impactions of organisms at the same location (Andersen 1958; Bellin and Schillinger 2001; Buttner et al., 1997a 2002b). Other frequently used impaction samplers with culture-based analysis are the SAS, Slit-to-Agar (STA), and RCS Plus (Buttner et al., 1997a and 2002b; Montacutelli et al., 2000). The SAS and RCS Plus samplers are battery-powered and commonly used in clean room environments (e.g., pharmaceutical and food processing facilities). These samplers operate at higher flow rates and can be pre-programmed to collected specific volumes of air, but the collection surface is smaller and overgrowth of fungi is common in environments with a high background population of organisms. Additionally, newly developed samplers are being designed to capture airborne microorganisms, especially for use as personal monitoring devices (Aizenberg et al., 2000).

Comparison of air samplers has shown that all these devices have advantages and disadvantages (Bellin and Schillinger 2001; Buttner and Stetzenbach 1993; Jensen et al., 1992; Smid et al., 1989). The smaller agar surfaces of the SAS and RCS Plus devices are a concern due to rapid spreading of some fungi over the smaller surface area making enumeration and identification difficult, but the requirement for electrical

power with the Andersen makes sampling in some buildings difficult if outlets are not readily available. Despite this limitation, the Andersen single-stage impactor sampler supplied with a broad-base fungal growth medium was used throughout this study. Malt extract agar (MEA) with 2% malt extract is widely used for the isolation of mesophilic fungi (Shelton et al., 2002) and is often amended with an antibacterial compound (i.e., chloramphenicol) to minimize the growth of bacteria that will grow quicker and mask the presence of fungi in the sample.

Total fungal spore samples for non-culturable microscopic assay are often collected using a slit sampler (Buttner et al., 1997a and 2002b) and analyzed with light microscopy. The Burkard personal impactor sampler (Burkard Manufacturing Co., Ltd., Rickmansworth Hertfordshire, England) is a battery-operated fixed flow rate (10 liters/min.) sampler. Samples are collected onto the sticky surface of a prepared glass microscope slide. The sampler must be decontaminated between the collection of samples. The Air-O-Cell air sampling cassettes (Zefon International, St. Petersburg, FL) are single-use samplers that require the use of an external vacuum pump operated at 15 liters/min. Rotorod and Kramer-Collison samplers have also been used for the collection of airborne spores, usually for outdoor samples (Cage et al., 1996). Direct sample slides are usually treated with a stain (e.g., lactophenol cotton blue) to enhance the discrimination of fungal structures. Filtration has been used for collection of fungal spores (Maggi et al., 2000) using mixed cellulose ester filters with filters either placed face up on culture media (Ellringer et al., 2000) or collected material is eluted from the filter membrane with a buffer and then inoculated to growth media. Filtration sampling is useful for monitoring in highly contaminated environments (Eduard et al., 1990; Palmgren et al., 1986; Thorne et al., 1992) because the sample can be diluted in the laboratory during processing thereby avoiding overloading of the agar surfaces, and the collected material can be examined with additional methods such as microscopy. Collection of airborne spores into liquid using impingement samplers is limited due to the hydrophobicity of many fungal spores, decreased culturability of vegetative bacteria due to increased sampling stress, and loss of collection buffer due to evaporation (Buttner et al., 1997a and 2002b).

Because of the variability inherent in air sampling and concern for false-negative results (Burge et al., 2000), surface sampling is used in conjunction with air sampling to characterize indoor environments (Duchaine and Meriaux 2001; Tiffany and Bader 2000). Vacuum sampling is used to sample porous or hard surfaces for settled particulate that may indicate the presence of fungal contaminants indoors (Hyvarinen et al., 2002a, 2002b, and 2002c). Sampling is conducted using an individual field filter cassette attached to a vacuum pump (e.g., mixed cellulose ester filters [Ellringer et al., 2000], polycarbonate [Hogdson and Scott 1999]) or a traditional vacuum cleaner (Macher 2001a and 2001b). Samples may be collected from materials (e.g., flooring, upholstery, and duct system components) over a defined area using a template (e.g., 0.1 m2) or the data can be reported per gram of sample processed. Samples for fungal analysis are blended with a known volume of a buffer solution, serially diluted, and plated to a variety of culture media (Macher 2001a and 2001b). Enumeration is reported as the number of colony forming units per area of sampled surface or per gram of collected material (Buttner et al., 1997a and 2002b; Ellringer et al., 2000; Hodgson and Scott 1999). Storage of samples for up to 25 days at refrigeration or room temperature has been shown not to affect the results (Macher 2001a and 2001b), but other researchers recommend storage at ≤-20°C (Koch et al., 2002).

Surveys comparing mold-damaged buildings and reference buildings have been conducted elsewhere (Hyvarinen et al., 2001b), but few studies have been conducted in the United States comparing buildings with varying characteristics (Su et al., 1992) and a database of non-problem office buildings is not currently available. These data would be valuable to assist in comparing office building across the United States and in the establishment of threshold limit values for exposure to biocontaminants (ACGIH 1999).

1.3 SOUND

Previous research found that sound is a major factor in occupant perception of the quality of their indoor environment. Beranek (1956) investigated occupant perception of their indoor environment and found that occupant perception of sound was primarily a function of sound level. Subsequent studies by other researchers determined that occupant perception was also a function of the frequency composition of the sound (Blazier 1981a, 1981b, 1995, and 1997; Boner 1994). Hanna (2002) conducted a study in Glasgow, Scotland, measuring over a typical workday the sound equivalent energy levels (Leq) of L10 and L90 values (the level exceeded 10 and 90 percent of the time respectively). The range between the L10 and L90 values was defined as the noise climate. A questionnaire determined occupant reaction to the sound, finding the problems related to sound were associated with a lack of concentration, distraction from work, annoyance, loss of performance and irritation. Hanna (2002) also concluded that the nature and content of sound rather than just its level cause occupant annoyance and dissatisfaction.

Office noise is often associated with ventilation and air-conditioning systems. Controlling sound levels from ventilations systems is one of the most important factors that contribute to the satisfaction of the system (Op't Veld and Passlack-Zwaans 1998). To ensure a healthy indoor environment and optimal performance of building occupants, the environment must be adjusted to desired thermal, visual, and acoustic conditions (Oral, Yener, and Bayazit 2004).

Zibrowski and Powers (2005; http://gepower.com_serv) compiled a glossary of sound terms. In this text the following terms are defined. A-weighting is defined as a frequence weighting that relates the response of the human ear. The term decibel (dB) is used when describing the degree of loudness and is expressed on a scale from zero for the average least perceptible sound to approx. 130 for the average pain level. Noise for a sound level meter reading with an A-weighting network simulating the human ear response at a loudness of 40 phons is termed dBA. The dBb is the loudness at a level of 70 phons and dBc is a sound level meter reading with no weighting network in the circuit (flat) and has a reference level of 20 microPa. A steady noise level or continous equivalent noise level is the time A-weighted average exposure (LeqA). LeqA is the steady noise level which over the period of time contains the same amount of sound energy as the time varying noise. L1 is the sound pressure level that is exceeded one percent of the time and L90 is the level of noise that is exceedd 90% of the time. Time weighted average exposure is important in for noise-at-work regulations and recommendations, where a maximum dBA level is measured over an eight hour working day. It is acceptable for a worker to be exposed to an average of 90 dBA for 1 hour every day with peak levels at 100 dB if for the remaining part of the day the individual sits in an office with an average noise level of e.g. 75 dBA (http://uswww03.gnnetcom/public). An acceptable sound level in an office area has been reported to be NCB 35 and LeqA - 43 (Unver et al., 2004).

In offices, there are a number of sources that produce low-frequency noise at moderate levels. These sources include ventilation systems and networking installations. Researchers have studied the effects of different noise sources, noise levels, as well as the effects of noise in conjunction with other factors. Studies on low-frequency noise, particularly ventilation noise, have showed that low-frequency noise has a negative impact on human comfort, health and performance. Characteristic symptoms of low-frequency noise reported are fatigue, lack of concentration, and headaches (Persson-Waye et al., 2001; Persson-Waye and Ryland 1997; and 2001). Also, Witterseh et al., (2002) discovered an increase of ventilation noise from 42 dBA to 45 dBA had a significant effect on the dissatisfaction rate. A study conducted by Persson-Waye and Ryland (2001) showed "psychological evidence of increased stress related to noise sensitivity and noise exposure during work." A ventilation noise level of 40 dBA was used in the study. In another study, Persson-Wayeet al., (2001) showed that it was more difficult to ignore or habituate to low-frequency noise. As a result, the performance of subjects decreased when exposed to elevated levels

of low-frequency noise. A recent study by Persson-Wayeet al., (2003) found lower levels of sleep quality and subject mood when exposed to nighttime low frequency noise.

Yamazaki and others (1998) studied the annoyance of indoor sound for different noise levels. Equivalent sound pressure levels ranging from 40 to 60 dBA were examined. They found that work suitability decreases monotonically as the sound level increases. In a study investigating annoyance and ventilation noise, Persson-Waye and Rylander (2001) observed that dBA noise levels were unable to predict annoyance. Research teams have studied annoyance in an assessment on the effects of sound on building occupants in real environments (Holmberg et al., 1996 and 1997). They rated sound according to dBLIN, dBA. dBB, dBC, dBD and the difference (dBC – dBA). They found that these levels alone did not correlate well with annoyance. Instead, they found significant correlation between the irregularity of the sound levels and annoyance and many complaints of low-frequency noise referred to its throbbing or pulsing nature.

The combination of noise and other factors produce effects that are not usually determined by an investigation performed investigating a single factor. Witterseh et al, (1999) combined ventilation noise with air pollution and observed that a 3 dBA noise level increase significantly increased the severity of headaches. Pellerin and Candas (2004) explored the combine effects of noise and heat. They found thermal unpleasantness increases when noise levels increase. Charles and Veitch (2002) investigated the effects of three workstation characteristics (area, minimum partition height, and windows) on privacy and other environmental factors. The statistic results showed that workstation area significantly predicted satisfaction with privacy including speech privacy.

The effects of noise are complex. Occupant response is related not only to the physical environment but also to their perception of the environment and their reactions towards them (Charles and Veitch 2002). As a result, subjective results may not correlate with physical measurements. For example, perceived enclosure accounted for 43% of the variance in satisfaction with privacy, whereas physical enclosure (measured as workstation area and average partition height) accounted for only 8% (Charles and Veitch 2002). This is contrary to the physics of sound where the partition height and continuity have a more significant effect on transmission loss than the mere existence of a physical enclosure. This suggests that perceptions of enclosure were formed from more than the actual physical effects resulting from the enclosure. Also, as noted above, there have been challenges in relating annoyance to an actual physical measurement. Other factors that affect occupant response to noise are the following: gender; job level; job complexity; organizational tenure; experience of alternative office environments; abilities to screen out distracting stimuli; personal need for privacy; and how one's workstation compares to both one's co-workers workstations and one's desired workstation.

Wittersehet al., (2002) observed that the effects of noise distraction depend on the job complexity. In this study, noise decreased the performance of an open-ended creative task; on the other hand, it improved typing speeds as well as proofreading speeds.

Several previous studies surveyed building occupants for their reaction to noise in terms of annoyance and distraction (Chiang and Lai 2002), but did not include the questionnaires or surveys administered to building occupants. The surveys/questionnaires fit in two general categories: those given to test subjects during laboratory experiments where the room environment is artificially manipulated and those given to occupants performing their normal tasks in actual functioning work areas. In laboratory experiments, the sounds are generally constant broadband noises that simulate air conditioning noise (Pellerin and Candas 2003; Toftum 2002; Witterseh et al., 1999). These surveys/questionnaires used in these studies reveal subject reaction to noise levels but cannot differentiate between noise sources or differentiated sensitivity to different characteristics in noise at equivalent levels. In the studies where occupants performing their normal tasks in actual functioning work areas were surveyed, the questions covered sound, thermal, lighting and air quality issues (Chiang and Lam 2002; Hanna 2002). The survey questions by Chiang and

Lai did not probe details of the noise character or seek the source of the noise. The occupants surveyed by Hanna worked in an old, historic building with little sound insulation. Noise sources and character were identified, and complaints centered on impulse and intermittent sound from moving furniture in the room one floor above.

The questionnaire used in this investigation was designed to extract occupants' perceptions of the sound environment and correlate their perceptions to field measurements of their workspaces. Questions asked occupants about their perceptions of thermal comfort, ventilation, IAQ, lighting, and sound in their workspaces. The questionnaire was designed to bridge gaps and also to expand on previous work to provide a complete picture of the reaction to sound in their work area by office occupants. It was compared to four major thermal/indoor air comfort questionnaires (ASHRAE 1998; Spagnolo and deDear 2003; Nakanoet al., 2002; CBE 2004). The questionnaire was designed to obtain sufficient data to verify or refute the following hypotheses:

- The levels of annoyance and distractions associated with sound will be greater when infrequent sound interruptions (sound levels temporarily increase by more than 5 dB over general background sound levels) exist.
- Sound interruptions (sound levels temporarily increase by more than 5 dB over general background sound levels) cause greater annoyance and distractions than more constant background sound levels associated with background masking and music systems or with the building ventilation system.
- Half of the sample population will be dissatisfied with sound when the sound source is a ventilation system and the sound level is above 45 dBA.
- The interaction of high ventilation sound levels and poor indoor air quality conditions increases the prevalence of Sick Building Syndrome (SBS) symptoms.
- Sound levels above 50 dBA dramatically affect the performance of office workers.
- As the noise level increases, thermal comfort decreases.
- Work performance of office workers is higher in closed offices than in open-spaces due to noise distractions.
- Low-frequency sound negatively affects work performance.
- dBLIN, dBA, dBC alone are poor indicators for annoyance.

It is anticipated that in the occupant perception questionnaire some responses by dissatisfied occupants will show wider variations than that cited in available standards. For example, previous field studies suggest ranges for thermal comfort provided by ASHRAE Standard 55 have not captured the expected percentages of satisfied/dissatisfied people in those studies (Schiller 1990).

1.4 LIGHTING

Lighting is responsible for about 20% to 25% of all electricity used in buildings and about 5% of total energy consumption in the United States. In addition, the heat dissipation from lighting fixtures accounts for 15% to 20% of the cooling load of HVAC systems. It is estimated that lighting and its associated cooling load constitute 30% to 40% of a nonresidential building's energy use. Obviously, lighting should be considered in studies regarding building energy conservation and building energy performance.

In the 1990s, the U.S. Environmental Protection Agency (1998) completed two studies: ORIA's Building Assessment Survey and Evaluation study and Temporal Indoor Monitoring Evaluation study. While they collected data from 156 buildings, the focus of the EPA studies was on indoor air quality, not lighting.

In the past ten years, the trend of office lighting design has changed significantly. More daylight is integrated into the office space, and indirect and direct/indirect lighting has become a more popular trend than direct lighting in new office buildings. In 2003, the allowable Lighting Power Density (LPD) was reduced from 1.3 to 1.0 W/ft², according to the ANSI/ASHARE/IESNA Standard (2003). All of these changes may significantly influence both the office lighting environment and occupants' satisfaction. This research will provide information on the lighting environment in relatively new office buildings and occupants' perceptions of their lighting environment.

The human body does not respond to an environmental input monotonically. Any response depends on a great number of factors, including indoor air quality, thermal comfort, lighting, and noise. However, most previous research regarding indoor environmental factors focused on air quality, thermal comfort and/or noise. Only a few studies focused on lighting. In the past ten years, no comprehensive field surveys considering all the parameters of indoor environmental quality included in this study (lighting, noise, thermal comfort, indoor air quality, and fungal contamination) have been conducted.

Significant research projects related to lighting field surveys in the United States were performed ten or more years ago. Ne'eman et al., (1984) collected lighting data and occupants' perceptions (n=162) of lighting of a nine-story office building in St. Louis, MO. The physical measurements included illuminance, source luminance, temperature, background sound levels and physical dimensions of representative furniture. The questionnaire asked occupants' perceptions and attitudes towards lighting, windows and lighting controls. The four-point rating scales were used in the questionnaire. Telephone surveys of occupants in office buildings were conducted for Steel Case Inc. to determine the importance of various features of the office environment (Harris, 1987). Approximately 1550 office workers took the survey. The results showed that 91% of occupants considered tasking lighting to be a very important factor for their task performance. Lighting was only one of the minor features investigated in the study.

Between 1984 and 1986, Collins et al. conducted a large-scale occupant evaluation survey for commercial office lighting (Collins et al., 1989, 1990; Gillette and Brown 1986, 1987; Marans and Brown 1987; and Sanders and Collins 1995). The research was sponsored by the DOE and the New York State Energy Research and Development Authority. The primary objective of this survey was to explore possible causal factors associated with successful lighting design with a special emphasis on the relationship between the lighting power load and subjective measure of lighting quality. Post-Occupancy Evaluation (POE) data were collected on LPD, photometric levels, and user attitudes for 912 workstations in 13 office buildings. Physical data were collected including illuminance, luminance, and other environmental measures. Questionnaire data were collected on the response to the lighting and general environment from 950 respondents. Questions were asked about the overall lighting satisfaction, amount of light for work, lighting for reading, glare, and whether lighting hindered them in performing their jobs. The conclusions from the survey by Collins et al. (1989, 1990) indicated that the majority of occupants (69%) were

satisfied with their lighting. The mean illuminances at the primary task location were within the IESNA design suggestions. The median LPD was approx. 2.36 W/ft², compared to the ASHARE/IESNA 90.1-2001 Addendum which requires 1.0 W/ft² for office buildings. The pattern of illuminances in the space rather than the illuminance on the task was a major determinant of lighting quality and satisfaction. Collins et al. (1990) in a second-level POE analysis found that occupants' satisfaction is related to the presence of daylight, but not directly related to the illuminance on the work surface. They also concluded that the pattern of luminances in the space is a more determinant factor to the lighting quality than the illuminance on the work surface.

Several results from this study were very controversial, however. Collins et al., found that occupants' satisfaction was consistently lower for workstations with furniture integrated task lighting. They also found higher rates of occupant satisfaction with direct lighting systems compared with indirect systems. In the study, fixed task lighting, combined with indirect ambient lighting systems, was rated as the lowest lighting quality and associated with noticeable dissatisfaction in the survey. However, the furniture integrated task lighting is still used widely in new office buildings, and indirect lighting, especially in combination with task lighting, is used in new offices more than ever before. Therefore, additional research is necessary to investigate these questionable issues.

Rubin and Collins (1988) conducted an environmental survey for three U.S. Army field stations. The survey included physical measurements of lighting, temperature, humidity, and noise. The illuminances were measured at primary task locations: the screen and keyboard of Visual Display Terminal (VDT) stations. Luminances were measured for a standard target which contained white, gray, and black surfaces. Luminances were also measured in the following locations: the ceiling (between luminaires); the brightest and darkest surfaces in the field of view; and the center, left, right, top and bottom of the VDT screens. The researchers also recorded the switching controls, types and positions of luminaires, and researchers' observations of the presence of visible reflections on the VDT screens. Occupants (n=621) responded to questionnaires which contained many questions related to lighting, brightness, flickering, glare, and occupants' satisfaction.

The results of Rubin and Collins study (1988) showed that illuminances were generally low for all areas of the building. The mean was 22 to 28 foot-candles (fc) for all areas and 12 to 20 fc for areas with VDTs. About 55% of occupants considered the lighting quality as fair to poor. To improve the general lighting conditions in these buildings, Rubin and Collins (1988) recommended the US army field station buildings use uniform lighting fixtures and lamps, better CRI sources, and higher overall illuminances, as well as adding adjustable task lighting for some workstations, and providing localized lighting controls.

Hedge (1991) evaluated two windowless offices, which were mainly used for computer tasks. Illuminance, temperature, and humidity levels were measured at work surfaces. Using a questionnaire, Hedge also collected data from 358 workers on complaints related to environmental conditions, lighting preference and job satisfaction and other issues. The results showed that indirect lighting was more favorably evaluated than parabolic direct lighting, which was inconsistent with the results from Collins and others (1990).

Sanders and Collins (1995) performed a post-occupancy evaluation on the Department of Energy Headquarters Building. Lighting measurements, occupant responses, and other environmental conditions were collected before and after a lighting retrofit. Physical measurements were conducted on 100 workstations before the lighting retrofit and on 75 workstations after the retrofit. There were 244 occupant respondents before the retrofit and 220 respondents after the retrofit. The physical measurements indicated that the lighting levels were higher and more evenly distributed after the retrofit. Post-evaluation techniques, including questionnaires and physical measurements, similar to the survey by Collins et al., (1990), were used. The occupant responses suggested that the appearance of the building

and lighting of individual workstations had been improved substantially, and the general lighting was evaluated more positively.

There are four principal methods of assessing human response to environments: subjective, objective, behavioral, and modeling (Parsons, 2000). With subjective methods, occupants report on their response to the environment by answering questionnaires. Subjective methods are easy to deploy and particularly appropriate for psychological responses such as comfort and annoyance. Objective methods directly measure the occupant. Examples include body temperature and speed and accuracy of the occupant's task performance. Objective methods, however, cannot predict psychological responses, such as comfort and satisfaction. With behavioral methods, behavior (e.g., changing posture and adjusting environment) is observed and recorded, but training observers and interpreting behavior remain considerable challenges to researchers. Finally, the modeling methods are used to predict human response based on previous investigations. However, modeling methods do not consider all the factors one may encounter in a real situation. Of these methods, subjective methods are the most appropriate to investigate occupants' perceptions toward building environments. Questionnaire tools are normally adopted for this purpose.

The physical measurements and perception questionnaire tools were developed based on these basic design issues and considerations for office lighting. The IESNA Lighting Handbook classifies design issues by importance. According to IESNA, the very important design issues of office lighting for intensive VDT use include direct glare, luminances of room surfaces, reflected glare, source/task/eye geometry and vertical illuminance. The important design issues include appearance of space and luminaires, color appearance, daylighting integration and control, flicker, lighting distribution on surface, lighting distribution on task plane, modeling of faces or objects, shadows, surface characteristics, and horizontal luminance.

Often, questions and questionnaires are designed for a specific building and used only once. Therefore, it is always very difficult to determine which questionnaires and methodologies are best-suited for obtaining accurate perceptions of occupants. As Hygge and Lofberg (1999) stated, "the important thing is that the main set of questions is preserved from one building to the next. In this way the knowledge about different buildings can be expanded and compared."

The lighting survey method adopted by most studies and with most available database was developed by Collins and others. (Collins et al., 1989, 1990; Gillette and Brown 1986, 1987; Marans and Brown 1987; and Sanders and Collins 1995). In this study, the data from 912 workstations and 950 questionnaires/surveys from 13 buildings were collected using this method. A similar method was adopted in later studies (Rubin and Collins 1988; Sanders and Collins 1995). Therefore, the physical measurements and questionnaire of our study were developed mainly based on this research.

The 24-question Tenant Survey Questionnaire was developed by National Research Council Canada (Tiller and Phil 1992) to determine whether occupants were satisfied with building services. Three questions were relevant to lighting systems; these asked the occupants to rate the lighting attributes (electrical lighting, brightness of lights, and glare from lights) of their particular desk location on five-point scales. The questionnaire used in this study included questions regarding these three lighting attributes. The National Research Council Canada researchers also developed a computer-based video photometer (CapCalc luminance and image analysis system) to capture luminance data in a visual scene. The bundled software evaluates visibility according to relative visual performance. However, the CapCalc luminance and image analysis system is used to evaluate visibility of a video scene and does not provide an overview of office lighting environments. In addition, the instrument is difficult to obtain. Therefore, it was not used in this study.

2. THERMAL COMFORT ASSESSMENT & HYPOTHESES

2.1 THERMAL COMFORT/IEQ

Part of this research project evaluated thermal comfort responses from the occupant participants in a questionnaire that was prepared with the cooperation of UNLV research staff and Verdi Technology Associates. The purpose of this questionnaire was to compare the engineering data obtained in the field with the occupants' perceptions of their work environment. This type of approach is common in thermal comfort studies (Schiller et al., 1988; deDearet al., 1994; deDear 1999; Donnini et al., 1999). The parameters studied in the questionnaire included temperature, humidity, draft, freshness, and odors. Kuskal-Wallis and Chi Square analyses were used for the analyses of data in this study.

Other research has developed and used questionnaires for occupants' perceptions of their work environments (Spagnolo et al., 1988; Nakano et al., 2002; CBE IEQ Survey on the web). This study emphasized a long term sampling approach at several fixed locations in the building by gathering data for three consecutive days to detect variances in thermal comfort conditions both over time and time of day. Past research and the ASHRAE 55-2004 standard obtained data in laboratory rooms using subjects whose feedback were obtained over a relatively short period and where thermal conditions were controlled. The situation in a typical study involves persons who occupy the office space for a relatively long period of time and on a daily basis during different seasons and at different times of operation of the HVAC units for that particular building. These varying office thermal conditions are suspected to create a variety of working conditions that may not be duplicated in a laboratory environment.

Differences between the current thermal comfort questionnaire and the ASHRAE questionnaire included the following:

- Use of a five-point Likert scale instead of a seven-point scale. Responses were rescaled using mean value (MV) calculations to calculate predicted mean vote (PMV) and predicted percentage of dissatisfied (PPD).
- More questions to gather more information about the immediate environment of the building's occupants.
- Questions to determine the effect of thermal comfort on the productivity of occupants.

The questionnaire was to be completed by the occupants on the day of monitoring by the UNLV survey team. The questionnaire was computer administered to a subset of all the occupants in the work area where measurements were collected. The questions were designed to obtain sufficient data to verify or refute their underlying hypotheses. The questionnaire was converted to a digitized format by Verdi Technology Associates. The final Word version of the questionnaire is listed in Appendix U.

Eleven hypotheses were posed to answer questions about the ability of the engineering data to predict the responses of building occupants regarding thermal comfort. The hypotheses rely on the ASHRAE Standard 55-2004 to define parameters for thermal comfort.

IEQ Hypothesis # 1: ≥80% of occupants in a building will be thermally comfortable if: temperatures are 27°C ≥ T_o ≥ 24°C (summer) and 24.5°C ≥ T_o ≥ 20°C (winter) and 0.012 kg ≥ W ≥ 0.0032kg of water/kg of dry air.

As defined by ASHRAE Standard 55-2004, the operative temperature (T_o) is measured and absolute humidity (W) is calculated from the measured relative humidity and other parameters. According to the comfort conditions provided by ASHRAE Standard 55-2004, there is a "box" on the psychometric chart (ASHRAE 55-2004, figure 5.2.1.1, p. 5) that is applicable for summer and

winter comfort conditions. This hypothesis addresses values of T_o and W for the overall temperature/humidity conditions to judge whether these conditions have been satisfied according to ASHRAE.

IEQ Hypothesis #2: There is a significant difference in thermal perception by occupants of mornings versus afternoons.

According to ASHRAE 55-2004 section 5.2.5, fluctuations in temperature can affect the perception of thermal comfort. In office buildings, HVAC equipment usually runs for only part of a day. In the mornings, HVAC equipment may take some time to achieve comfortable thermal conditions at the beginning of the workday due to the large thermal inertia of the structure of the office building. This hypothesis also uses T_o and AH values.

IEQ Hypothesis #3: ≤10% of occupants will make adjustments to their work area to make it more thermally comfortable.

This hypothesis predicts what typical occupants might do faced with options of either being too cool or too warm.

IEQ Hypothesis #4: If the occupants' work areas are thermally unacceptable, the occupants in that area will work less efficiently (i.e., less productively).

These four questions focus on the perception of being unproductive due to thermally unacceptable conditions. The CBE questionnaire (**APPENDIX A)** is the only one of those cited that probes the perception of the occupants regarding productivity.

IEQ Hypothesis #5: The occupants of a building will be thermally comfortable if the vertical temperature gradient is ≤3.0 °C.

ASHRAE Standard 55-2004 (sect. 5.2.4.3 p. 8) indicates potential vertical temperature difference (temperatures over the body) as a possibility for thermal discomfort.

IEQ Hypothesis #6: <15% of building occupants should feel a draft anywhere if the draft rate/percent feeling draft is ≤15%. If the draft rate is ≥15%, ≥80% of occupants in a building should feel comfortable.

The draft rate/percent feeling draft (DR, PD) is explained earlier indicating its relationship to the ambient air temperature, local mean air speed and the mean turbulent intensity of air locally. ASHRAE Standard 55-2004 has also alluded to this effect as a potential cause for thermal discomfort in section 5.2.4.2.

IEQ Hypothesis #7: ≤20% of occupants will make adjustments to their environment to reduce the presence of a draft in their work environment.

This hypothesis considers what action the occupants will take to mitigate the effects of perceived excessive draft.

IEQ Hypothesis #8: Eighty percent or more of the occupants in a work area will not feel stuffy if the indoor to outdoor differential concentration of CO_2 is not greater than about 700 ppm.

The specified ventilation rates and occupant densities for specified spaces listed in ASHRAE Standard 62 "reflect the consensus that the provision of acceptable outdoor air at these rates would achieve an acceptable level of indoor air quality by reasonably diluting human bioeffluents, particulate matter, odors, and other contaminants common to those spaces."

IEQ Hypothesis#9: Occupants who perceive the air in their work area as stuffy or stagnant will make adjustments to make their work area more comfortable.

The common belief is occupants who perceive air as stuffy or stagnant will do something to avoid, change or speak out.

IEQ Hypothesis#10: If the occupants feel the air in their work place as stuffy or stagnant, or smell unpleasant odors, they will likely work less efficiently.

Work place occupants who report physical discomfort may suffer reduced work productivity (ASHRAE RP 921; Cena and de Dear, 1998).

IEQ Hypothesis#11: If occupants smell unpleasant odors in their work area, some of them will be uncomfortable and make adjustments to reduce the concentration of odor.

Ventilation, a key element in building design, is necessary for supporting life by maintaining acceptable levels of oxygen in the air, preventing CO_2 from rising to unacceptably high concentrations, and removing internally produced odor, moisture, and pollution (ASHRAE Standard 62). Occupants will take action to change something in their immediate surroundings to mitigate the effect of odors.

2.2 AIRBORNE AND SURFACE-ASSOCIATED MOLD

Mold Hypothesis#1: In outdoor air, a mixed population of airborne fungus is expected with no one genus except Cladosporium predominating and the distribution of which will vary by geographic region.

Spores of the mold *Cladosporium* are the most common airborne fungal spores worldwide (Lighthart and Stetzenbach, 1994; Shelton et al., 2002). Mixed populations of fungal spores are normative and expected in urban outdoor environments.

Mold Hypothesis#2: Among non-problem buildings, a mixed population of airborne fungus is expected with no one genus except Cladosporium predominating and the distribution of which will vary by geographic region.

Due to the abundance of *Cladosporium* worldwide, spores of this mold or mixed populations of fungal spores indoors in non-problem buildings are normative and expected (Samson et al., 2001.

Mold Hypothesis#3: The concentration of airborne fungal genera present in non-problem buildings should reflect the outdoor fungal population in that region.

Outdoor fungal populations are the source for indoor populations (Lighthart and Stetzenbach, 1994; Shelton et al., 2002). In non-water damaged indoor environments, the airborne fungal populations should reflect that found in the outdoor air (Samson et al., 2001).

Mold Hypothesis#4: The ranges of concentration of airborne total spores observed with non-culturable air sampling and the number of colony-forming units (CFU) of culturable fungal particles isolated with culturable air sampling in non-problem buildings are expected to be similar (<1 order of magnitude, <10X difference) at different sampling locations in the building.

Because the indoor fungal populations should reflect that found in the outdoor air, the concentrations indoors should be similar to that found in the outdoors (Lighthart and Stetzenbach, 1994, Samson et al., 2001, Shelton et al., 2002).

Mold Hypothesis#5: The ranges of concentration of airborne total spores observed with non-culturable air sampling and the number of colony-forming units (CFU) of culturable fungal particles isolated with culturable air sampling in non-problem buildings are expected to be similar (<1 order of magnitude, <10X difference) on different days of sampling.

In non-problem buildings, the concentrations and populations of airborne culturable fungi and fungal spores should not vary by the day of sample collection.

Mold Hypothesis#6: Between non-problem buildings, both types of air samples are expected to show the same genera of fungi, with <1 order of magnitude difference in concentration and absence of atypical fungi.

The fungal populations in non-problem buildings should be similar in concentration and water-indicating fungal genera should be absent (Samson et al., 2001).

Mold Hypothesis#7: Among non-problem buildings, a mixed population of fungi in the surface dust is expected with no one genus except Cladosporium predominating and the distribution of which will vary by geographic region.

Fungal spores will settle from the air onto surfaces and settled spores may become reaerosolized (Buttner et al., 2002a). The populations of fungi in settled dust in non-problem buildings should reflect that found in the air samples as mixed populations with no genus except *Cladosporium* present as the predominant organism (Horner et al., 2004).

Mold Hypothesis#8: The concentrations of surface-associated fungal genera present in non-problem buildings are consistent among buildings.

Variation in the concentrations of culturable fungi in settled dust in non-problem buildings should be minimal as the populations are reflective of that settled from the indoor air (Buttner et al., 2002a).

Mold Hypothesis#9: The concentration of culturable fungi in non-problem buildings is expected to be ≤10^5 CFU/gram of dust.

Studies have reported populations of fungi in settled dust to be ≤10^5 CFU/g (Ellringer et al., 2000, Stetzenbach 2002).

Mold Hypothesis#10: The range of concentration of surface-associated culturable fungi in dust samples collected in non-problem buildings is expected to be similar (<1 order of magnitude, <10X difference) at different sampling locations in the building.

Variation in the concentrations of culturable fungi in settled dust in non-problem buildings should be minimal as the populations are reflective of that settled from the indoor air (Buttner et al., 2002a).

Mold Hypothesis#11: Within the same building at different times of day in the same location, the same genera of fungi are expected to be measured in dust samples, with up to a 1 order of magnitude difference in concentration.

Minimal variation in the concentrations and populations of fungi in settled dust in non-problem buildings is expected as these organisms are present as background populations (Ellringer et al., 2000, Hodgson and Scott 1999).

Mold Hypothesis#12: Regional differences between non-problem buildings are reflected in the different surface dust composition of fungal genera.

Regional differences in fungal populations would be reflected in the populations of fungi in settled dust.

Mold Hypothesis#13: "Indicator" fungi (i.e., indicators of water intrusion/moisture accumulation of building materials capable of promoting mold growth) are expected to be "not present" in air samples in non-problem buildings.

Fungal genera associated with water intrusion/water damage are not present in the air of non-problem buildings (Samson et al., 2001).

Mold Hypothesis#14: "Indicator" fungi (i.e., indicators of water intrusion/moisture accumulation of building materials capable of promoting mold growth) are expected to be "not present" in surface dust samples in non-problem buildings.

Fungal genera associated with water intrusion/water damage are not present in the surface dust of non-problem buildings (Horner et al., 2004).

2.3 SOUND

Sound Hypothesis# 1: Sound in a work area can annoy or distract occupants.

Sound in a work area can annoy or distract workers. dBLIN, dBA, dBC do not predict annoyance and distraction associated with sound with a confidence level above 70%, and noise criteria (NC), nosie reduation (NR), PNC and NCB do not predict annoyance and distraction associated with sound with a confidence level above 80%. Bies and Hansen (1997) cover limitations in the various measurement criteria. Holmberg, Landstrom, and Kjellberg (1997) found that dBLIN, dBA, dBB, dBC, and dBD and the difference (dBC – dBA) alone did not correlate well with annoyance (Beis and Hansen 1997). As a general guideline, the levels of annoyance and distractions associated with sound will be greater when the reverberation time of the building is greater than 0.8 seconds. However, the reverberation time changes with different occupancy levels effecting speech intelligibility (Beranek 1993). There is also some evidence that high sound levels simultaneous with temperature outside the normal range result in higher incidence of annoyance and distraction than either condition alone (Pellerin and Candas 2004).

Sound Hypothesis#2: There is variation in an occupant's preferences and tolerances to sounds or noise in the work area.

It can be assumed that in every perception measure ever performed on human subjects, variation exits in the subjects' perceptions of the measures. Some perception differences in sound can be physiological (e.g., hearing loss with age and increased sensitivity to loud noises with age). Other differences can be psychological or task related, such as wanting quiet when concentrating. Such differences may help explain why standard measures often do not correlate well with annoyance (Holmberg et al., 1996; Holmberg, Landstrom, and Kjellberg 1997). Information on the building occupant's preferences toward sound will help with the correlation of perception data to field data.

Sound Hypothesis#3: Sound in a work area can fluctuate during the day.

It can be assumed that in many buildings, outdoor activity, work schedules, work activities, and building equipment operations can cause fluctuations in sound levels during the day. Research has shown that fluctuations in sound levels and characteristics in the office can be a source of annoyance (Holmberg et al., 1996; Holmberg, Landstrom, and Kjellberg 1997). Determining occupants' perceptions of that fluctuation can be compared to actual fluctuations and perceptions of the acceptability of sounds and noise in the work area.

Sound Hypothesis#4: Intruding sound in a work area can come from one or more of the following sound sources: (1) sound from outside the building, (2) conversations in adjacent areas, (3) telephone/speakerphones conversations, (4) building masking system, piped-in music, paging system, (5) nearby office equipment, (6) HVAC mechanical equipment, and (7) ceiling, wall, and/or floor air-supply or return air diffusers.

This hypothesis is based on the 2005 ASHRAE Applications Handbook and collective knowledge of the investigators.

Sound Hypothesis#5: Sound in the work area that comes from outside the building can annoy or distract occupants.

Annoying or distracting sound from outside the building can come from various sources (collective knowledge of the investigators).

Sound Hypothesis#6: Annoyance or distraction from outside sound can be caused by the overall sound level, the intermittent nature (on-off cycle) of the sound, time variations in the sound intensity, or irritating or harsh tones contained in the sound.

Annoyance and distraction can come from various characteristics of the sound including intensity, intermittency, fluctuations in intensity, and tonal or harsh character (Hanna 2002). Half of the sample population will be dissatisfied with sound when the background sound level is above 45 dBA, while half of the sample population will be dissatisfied with sound and report decreased work efficiency when the background sound level is above 50 dBA. Guidelines for maximum noise in different environments are available (Beranek 1993; Persson-Waye and Rylander 2001b; Unver et al., 2004; Witterseh, Clausen, and Wyon 2002; Witterseh et al., 1999; Yamazaki et al., 1998). The levels of annoyance and distractions associated with sound will be greater when infrequent sound interruptions (sound levels temporarily, about 10% of the time, more than 5 dB over general background sound levels) exist. Different studies give varying levels of the intermittent noise that causes complaints (Westman and Walters 1981; Witterseh, Clausen, and Wyon 2002). The levels of annoyance and distractions associated with sound will be greater when fluctuations in the sound intensity of more than 5 dB over general background sound levels exist. Leventhall and others (2003) made note of this for low frequency noise. The levels of annoyance and distractions associated with sound will be greater when one or more one-third octave band sound levels are more than 5 dB over overall sound levels exist. Strong tonal content has been noted for its irritation and common guidelines specify lower maximum acceptable noise levels when tonal content is significant (Beis and Hansen 1997; Beranek 1993).

Sound Hypothesis#7: Sound in a work area from telephone speakerphone conversations in adjacent work can annoy or distract building occupants.

The levels of annoyance and distractions associated with sound will be greater than otherwise when sound content dominated by conversations and speakerphones exist. Intelligibility versus background noise can make sound more difficult to ignore. The speakerphone frequency spectrum, which is narrow and centered around the most sensitive region of human hearing, adds extra harshness to its sound (collective knowledge of the investigators).

Sound Hypothesis#8: Annoyance or distraction from sound from telephone conversations and speakerphones in adjacent work areas can be caused by the overall sound level, the intermittent nature of the sound, the intelligibility or content of the sound, or the irritating or harsh content in the sound.

Annoyance and distraction can come from various characteristics of the sound including intensity, intermittency, fluctuations in intensity, and tonal or harsh character (Hanna 2002). Half of the sample population will be dissatisfied with sound when the background sound level is above 45 dBA, while half of the sample population will be dissatisfied with sound and report decreased work efficiency when the background sound level is above 50 dBA. Guidelines for maximum noise in different environments are available (Beranek 1993; Persson-Waye and Rylander 2001b; Unver et al., 2004; Witterseh, Clausen, and Wyon 2002; Witterseh et al., 1999; Yamazaki et al., 1998). The levels of annoyance and distractions associated with sound will be greater when infrequent sound interruptions (sound levels temporarily, about 10% of the time, more than 5 dB over general background sound levels) exist. Different studies give varying levels

of the intermittent noise that causes complaints (Westman and Walters 1981; Witterseh, Clausen, and Wyon 2002). The levels of annoyance and distractions associated with sound will be greater when fluctuations in the sound intensity of more than 5 dB over general background sound levels exist. Leventhall and others (2003) made note of this for low frequency noise. The levels of annoyance and distractions associated with sound will be greater when one or more one-third octave band sound levels are more than 5 dB over overall sound levels exist. Strong tonal content has been noted for its irritation and common guidelines specify lower maximum acceptable noise levels when tonal content is significant (Beis and Hansen 1997; Beranek 1993).

In addition, the levels of annoyance and distractions associated with sound will be greater than otherwise when sound content dominated by conversations and speakerphones exist. Intelligibility versus background noise can make sound more difficult to ignore. The speakerphone frequency spectrum, which is narrow and centered around the most sensitive region of human hearing, adds extra harshness to its sound (collective knowledge of the investigators).

Sound Hypothesis#9: Sound in a work area from conversations in adjacent work areas can annoy or distract building occupants.

The levels of annoyance and distractions associated with sound will be greater than otherwise when sound content dominated by conversations and speakerphones exist. Intelligibility versus background noise can make sound more difficult to ignore. The speakerphone frequency spectrum, which is narrow and centered around the most sensitive region of human hearing, adds extra harshness to its sound (collective knowledge of the investgators).

Sound Hypothesis#10: Annoyance or distraction from sound from conversations in adjacent work areas can be caused by the overall sound level, the intermittent nature of the sound, the intelligibility or content of the sound or the irritating or harsh content in the sound.

Annoyance and distraction can come from various characteristics of the sound including intensity, intermittency, fluctuations in intensity, and tonal or harsh character (Hanna 2002). Half of the sample population will be dissatisfied with sound when the background sound level is above 45 dBA, while half of the sample population will be dissatisfied with sound and report decreased work efficiency when the background sound level is above 50 dBA. Guidelines for maximum noise in different environments are available (Beranek 1993; Persson-Waye and Rylander 2001b; Unver et al., 2004; Witterseh, Clausen, and Wyon 2002; Witterseh et al., 1999; Yamazaki et al., 1998). The levels of annoyance and distractions associated with sound will be greater when infrequent sound interruptions (sound levels temporarily, about 10% of the time, more than 5 dB over general background sound levels) exist. Different studies give varying levels of the intermittent noise that causes complaints (Westman and Walters 1981; Witterseh, Clausen, and Wyon 2002). The levels of annoyance and distractions associated with sound will be greater when fluctuations in the sound intensity of more than 5 dB over general background sound levels exist. Leventhall and others (2003) made note of this for low frequency noise. The levels of annoyance and distractions associated with sound will be greater when one or more one-third octave band sound levels are more than 5 dB over overall sound levels exist. Strong tonal content has been noted for its irritation and common guidelines specify lower maximum acceptable noise levels when tonal content is significant (Beis and Hansen 1997; Beranek 1993).

In addition, the levels of annoyance and distractions associated with sound will be greater than otherwise when sound content dominated by conversations and speakerphones exist. Intelligibility versus background noise can make sound more difficult to ignore. The speakerphone frequency spectrum, which is narrow and centered around the most sensitive region of human hearing, adds extra harshness to its sound (collective knowledge of the investogators).

Sound Hypothesis#11: Sound in a work area from building piped-in music, and background-masking system can annoy or distract building occupants.

While often inserted for speech privacy, paging, speaker music, and background masking sounds can be annoying and distracting, especially for work that requires high levels of concentration (Beis and Hansen 1997).

Sound Hypothesis#12: Annoyance or distraction from sound from a building masking or piped-in music system in adjacent work areas can be caused by the overall sound level, the intermittent nature of the sound, fluctuations in the sound intensity or the irritating or harsh content in the sound.

Annoyance and distraction can come from various characteristics of the sound including intensity, intermittency, fluctuations in intensity, and tonal or harsh character (Hanna 2002). Half of the sample population will be dissatisfied with sound when the background sound level is above 45 dBA, while half of the sample population will be dissatisfied with sound and report decreased work efficiency when the background sound level is above 50 dBA. Guidelines for maximum noise in different environments are available (Beranek 1993; Persson-Waye and Rylander 2001b; Unver et al., 2004; Witterseh, Clausen, and Wyon 2002; Witterseh et al., 1999; Yamazaki et al., 1998). The levels of annoyance and distractions associated with sound will be greater when infrequent sound interruptions (sound levels temporarily, about 10% of the time, more than 5 dB over general background sound levels) exist. Different studies give varying levels of the intermittent noise that causes complaints (Westman and Walters 1981; Witterseh, Clausen, and Wyon 2002). The levels of annoyance and distractions associated with sound will be greater when fluctuations in the sound intensity of more than 5 dB over general background sound levels exist. Leventhall and others (2003) made note of this for low frequency noise. The levels of annoyance and distractions associated with sound will be greater when one or more one-third octave band sound levels are more than 5 dB over overall sound levels exist. Strong tonal content has been noted for its irritation and common guidelines specify lower maximum acceptable noise levels when tonal content is significant (Beis and Hansen 1997; Beranek 1993).

Sound Hypothesis#13: Sound in a work area from nearby office equipment (copy machines, typewriters, etc.) can annoy or distract building occupants.

Office equipment is an ever-present potential source for significant noise. Office equipment has changed considerably over the last decade, requiring repeat evaluation of the importance of the noise it generates (collective knowledge of the investigators).

Sound Hypothesis#14: Annoyance or distraction from nearby office equipment (copy machines, typewriters, etc.) can be caused by the overall sound level, the intermittent nature of the sound, fluctuations in the sound intensity or the irritating or harsh tones contained in the sound.

Annoyance and distraction can come from various characteristics of the sound including intensity, intermittency, fluctuations in intensity, and tonal or harsh character (Hanna 2002). Half of the sample population will be dissatisfied with sound when the background sound level is above 45 dBA, while half of the sample population will be dissatisfied with sound and report decreased work efficiency when the background sound level is above 50 dBA. Guidelines for maximum noise in different environments are available (Beranek 1993; Persson-Waye and Rylander 2001b; Unver et al., 2004; Witterseh, Clausen, and Wyon 2002; Witterseh et al., 1999; Yamazaki et al., 1998). The levels of annoyance and distractions associated with sound will be greater when infrequent sound interruptions (sound levels temporarily, about 10% of the time, more than 5 dB over general background sound levels) exist. Different studies give varying levels of the intermittent noise that causes complaints (Westman and Walters 1981; Witterseh, Clausen,

and Wyon 2002). The levels of annoyance and distractions associated with sound will be greater when fluctuations in the sound intensity of more than 5 dB over general background sound levels exist. Leventhall and others (2003) made note of this for low frequency noise. The levels of annoyance and distractions associated with sound will be greater when one or more one-third octave band sound levels are more than 5 dB over overall sound levels exist. Strong tonal content has been noted for its irritation and common guidelines specify lower maximum acceptable noise levels when tonal content is significant (Beis and Hansen 1997; Beranek 1993).

Sound Hypothesis#15: Sound in a work area from ceiling or floor air-supply diffusers can annoy or distract building occupants.

Sound from the mechanical equipment (e.g., fans, air-conditioning compressors, pumps) and ceiling, wall, or floor air-supply diffusers is the major source of noise in most office buildings. The sound can propagate into the work area by various means including through walls, ducting, and building structures (ASHRAE 1995).

Sound Hypothesis#16: Annoyance or distraction from air-supply or return-air diffusers can be caused by the overall sound level, the intermittent nature of the sound, fluctuations in the sound intensity or the irritating or harsh tones contained in the sound.

Annoyance and distraction can come from various characteristics of the sound including intensity, intermittency, fluctuations in intensity, and tonal or harsh character (Hanna 2002). Half of the sample population will be dissatisfied with sound when the background sound level is above 45 dBA, while half of the sample population will be dissatisfied with sound and report decreased work efficiency when the background sound level is above 50 dBA. Guidelines for maximum noise in different environments are available (Beranek 1993; Persson-Waye and Rylander 2001b; Unver et al., 2004; Witterseh, Clausen, and Wyon 2002; Witterseh et al., 1999; Yamazaki et al., 1998). The levels of annoyance and distractions associated with sound will be greater when infrequent sound interruptions (sound levels temporarily, about 10% of the time, more than 5 dB over general background sound levels) exist. Different studies give varying levels of the intermittent noise that causes complaints (Westman and Walters 1981; Witterseh, Clausen, and Wyon 2002). The levels of annoyance and distractions associated with sound will be greater when fluctuations in the sound intensity of more than 5 dB over general background sound levels exist. Leventhall and others (2003) made note of this for low frequency noise. The levels of annoyance and distractions associated with sound will be greater when one or more one-third octave band sound levels are more than 5 dB over overall sound levels exist. Strong tonal content has been noted for its irritation and common guidelines specify lower maximum acceptable noise levels when tonal content is significant (Beis and Hansen 1997; Beranek 1993).

Sound Hypothesis#17: Annoying or distracting sound from ceiling or floor air-supply diffusers can come from various room boundaries.

Sound from the mechanical equipment (e.g., fans, air-conditioning compressors, pumps) and ceiling, wall, or floor air-supply diffusers is the major source of noise in most office buildings. The sound can propagate into the work area by various means including through walls, ducting, and building structures (ASHRAE 1995).

Sound Hypothesis#18: Annoying or distracting sound from ceiling or floor air-supply diffusers can have predominant distinguishing characteristics.

Sound from the mechanical equipment (e.g., fans, air-conditioning compressors, pumps) and ceiling, wall, or floor air-supply diffusers is the major source of noise in most office buildings.

The sound can propagate into the work area by various means including through walls, ducting, and building structures (ASHRAE 1995).

Sound Hypothesis#19: Annoying or distracting sound from ceiling or floor air-supply diffusers can originate from mechanical equipment.

Sound from the mechanical equipment (e.g., fans, air-conditioning compressors, pumps) and ceiling, wall, or floor air-supply diffusers is the major source of noise in most office buildings. The sound can propagate into the work area by various means including through walls, ducting, and building structures (ASHRAE 1995).

Sound Hypothesis#20: Annoying or distracting sound from ceiling or floor air-supply diffusers can originate from conversations elsewhere in the building.

Conditions that allow building occupants to clearly hear talking in person or by telephone or speakerphone can cause building occupants to delay or postpone a private conversation in their work area. The levels of annoyance and distractions associated with sound will be greater when the inter-zone sound transmission loss is less than 10 dB in the 500 to 2000 Hz range. The size of the workstation also correlates with worker perception of privacy. Witterseh and others 2002) and Witterseh, Clausen, and Wyon (1999) provide qualitative information concerning privacy for open offices versus private offices.

Sound Hypothesis#21: Sound in a work area from mechanical equipment within a building can annoy or distract occupants.

Sound from the mechanical equipment (e.g., fans, air-conditioning compressors, pumps) and ceiling, wall, or floor air-supply diffusers is the major source of noise in most office buildings. The sound can propagate into the work area by various means including through walls, ducting, and building structures (ASHRAE 1995).

Sound Hypothesis#22: Annoyance or distraction from mechanical equipment within the building can be caused by the overall sound level, the intermittent nature of the sound, fluctuations in the sound intensity or the irritating or harsh tones contained in the sound.

Annoyance and distraction can come from various characteristics of the sound including intensity, intermittency, fluctuations in intensity, and tonal or harsh character (Hanna 2002). Half of the sample population will be dissatisfied with sound when the background sound level is above 45 dBA, while half of the sample population will be dissatisfied with sound and report decreased work efficiency when the background sound level is above 50 dBA. Guidelines for maximum noise in different environments are available (Beranek 1993; Persson-Waye and Rylander 2001b; Unver et al., 2004; Witterseh, Clausen, and Wyon 2002; Witterseh et al., 1999; Yamazaki et al., 1998). The levels of annoyance and distractions associated with sound will be greater when infrequent sound interruptions (sound levels temporarily, about 10% of the time, more than 5 dB over general background sound levels) exist. Different studies give varying levels of the intermittent noise that causes complaints (Westman and Walters 1981; Witterseh, Clausen, and Wyon 2002). The levels of annoyance and distractions associated with sound will be greater when fluctuations in the sound intensity of more than 5 dB over general background sound levels exist. Leventhall and others (2003) made note of this for low frequency noise. The levels of annoyance and distractions associated with sound will be greater when one or more one-third octave band sound levels are more than 5 dB over overall sound levels exist. Strong tonal content has been noted for its irritation and common guidelines specify lower maximum acceptable noise levels when tonal content is significant (Beis and Hansen 1997; Beranek 1993).

Sound Hypothesis#23: Annoying or distracting sound from mechanical equipment within a building can come from various room boundaries.

Sound from the mechanical equipment (e.g., fans, air-conditioning compressors, pumps) and ceiling, wall, or floor air-supply diffusers is the major source of noise in most office buildings. The sound can propagate into the work area by various means including through walls, ducting, and building structures (ASHRAE 1995).

Sound Hypothesis#24: Annoying or distracting sound from mechanical equipment within a building can have predominant distinguishing characteristics.

The levels of annoyance and distractions associated with sound will be greater when sound content is dominated by low frequency sound levels (below 250 Hz) and sound levels more than 10 dB over overall exist (Leventhall et al., 2003).

Sound Hypothesis#25: Conditions that allow building occupants to clearly hear talking in person or by telephone or speakerphone can cause workers to believe that they cannot have a private conversation in their work area.

Conditions that allow building occupants to clearly hear talking in person or by telephone or speakerphone can cause building occupants to delay or postpone a private conversation in their work area. The levels of annoyance and distractions associated with sound will be greater when the inter-zone sound transmission loss is less than 10 dB in the 500 to 2000 Hz range. The size of the workstation also correlates with worker perception of privacy. Witterseh and others 2002) and Witterseh, Clausen, and Wyon (1999) provide qualitative information concerning privacy for open offices versus private offices.

Sound Hypothesis#26: Building occupants take positive action to mitigate a distracting or annoying noise.

Unwanted noise can be enough of a distraction or annoyance to building occupants to motivate them to take what they consider appropriate action to mitigate the noise. If the noise is caused by conversations the simplest action is to ask the persons to be quiet or move.

Sound Hypothesis#27: If building occupants believe they cannot have a private conversation in their work area, they will move to a more private area for confidential conversations.

Conditions that allow building occupants to clearly hear talking in person or by telephone or speakerphone can cause building occupants to delay or postpone a private conversation in their work area. The levels of annoyance and distractions associated with sound will be greater when the inter-zone sound transmission loss is less than 10 dB in the 500 to 2000 Hz range. The size of the workstation also correlates with worker perception of privacy. Witterseh and others 2002) and Witterseh, Clausen, and Wyon (1999) provide qualitative information concerning privacy for open offices versus private offices.

Sound Hypothesis#28: If building occupants believe they cannot have a private conversation in their work area, they will postpone confidential conversations to a time when people are not present in adjacent areas.

2.4 LIGHTING

Lighting Hypothesis#1: Most people will be comfortable when the lighting in their work areas is neither too bright nor too dim.

Collins et al. (1989, 1990) reported that the pattern of illuminances in the space rather than the illuminance on the task was a major determinant of lighting quality and satisfaction. Collins et al. (1990) also found that occupants' satisfaction is related to the presence of daylight, but not directly related to the illuminance on the work surface and that the pattern of luminances in the space is a more determinant factor to the lighting quality than the illuminance on the work surface.

Lighting Hypothesis#2: The lighting over 700 Lux on the work surface will be considered as "very bright" or "somewhat bright" and lower than 300 Lux may be considered as "very dim or dark" or "somewhat dim or dark".

IESNA Lighting Handbook, ASHARE/IESNA 90.1-2001 and addendum, ANSI/ASHARE/IESNA Standard (2003), and experience of researcher.

Lighting Hypothesis#3: Lower than 50 Lux of the lighting at computer screens will be considered as "very dim or dark" or somewhat dim or dark".

IESNA Lighting Handbook, ASHARE/IESNA 90.1-2001 addendum, ANSI/ASHARE/IESNA Standard (2003), and experience of researcher.

Lighting Hypothesis#4: The uniformity of illuminance less 3 at work surfaces will be considered as uniform.

IESNA Lighting Handbook, ASHARE/IESNA 90.1-2001 addendum, ANSI/ASHARE/IESNA Standard (2003), and experience of researcher.

Lighting Hypothesis#5: When there is too much glare on desk surfaces or workstations, and/or on my computer screen, most occupants' productivity will be adversely affected.

Tiller and Phil 1992, Sanders and Collins, 1995, and experienceof researcher.

Lighting Hypothesis#6: Most people prefer to have natural light from outdoors come into their office or work area.

Hedge 1991 and experience of researcher.

Lighting Hypothesis#7: If the CRI of lighting is 75 or greater, the color of people's faces and objects in work area will appear natural.

IESNA Lighting Handbook

Lighting Hypothesis#8: The CCT of the lighting lower than 3000 K will be evaluated as visually warm and higher than 5000 will be evaluated as visually cool.

IESNA Lighting Handbook

3. METHODS

3.1 BUILDING

3.1.1 Building Selection Criteria

Prior to making contact with the administration at a prospective building, information about the building was collected via the Internet. The building selection criteria were designed to qualify a list of potential non-problem buildings. The criteria focused on the general use of the building, the history of the building, the location, the construction time, and the ventilation system. These questions helped determine whether to include or exclude a building based on the outlined criteria. The building selection criteria are listed in Appendix B.

3.1.2 Building Recruitment

The initial building recruitment strategy involved direct solicitation in the form of an invitation letter to the building manager. The letter's objective was to notify the manager of the researcher's interest in the building and to request a telephone conversation to discuss the building's participation further. Once one-on-one communication was established, the project liaison posed the building selection questions to determine whether or not the building met participation requirements.

3.1.3 Building Selection General Questions

Strategy for the selection of non-problem buildings involved several components. Major components were types of structures, geographical locations, and the building's maintenance history. Screening also included number of floors, the number of daily occupants, and employees' ability to participate in the occupation perception questionnaire. The selection questions were asked by the project liaison in a conversation with the building managers via telephone. The building selection general questionnaire is listed in Appendix C.

3.1.4 Building Characterization Questionnaire

A more advanced building characterization questionnaire was then sent to building managers of those buildings that met the requirements addressed in the two previous selection screenings. This questionnaire was used to ascertain the more detailed features of the building in a comprehensive manner. Questions focused on multiple aspects of the building's demographics. The physical characteristics (e.g., age of building, amount of windows, total square footage), the types of materials used (e.g., flooring, lighting, ceiling) and the mechanical systems (e.g., HVAC system, the energy management system) were asked in the questionnaire. Building characteristics questionnaires were completed by facility managers. The building characterization questionnaire is listed in Appendix D.

3.1.5 Procedure to Generate MLID

MLID stands for "Minor location ID." The MLID is unique to all sampling zones from all buildings. Users can use the MLID to extract information from any specific sampling zone within a specific building. The MLID is generated sequentially by the Microsoft (MS) Visual Basic (VB) code implemented within the MS ACCESS database.

3.2 INDOOR ENVIRONMENTAL QUALITY

The IEQ parameters include thermal comfort, CO_2, and VOCs.

3.2.1 Thermal Comfort

Six stationary stations obtained data over three days. These stations were usually placed in spaces that would give an overall evaluation of the differences in space allocations in a typical office building (i.e. individual offices versus open spaces). The methods including descriptions of equipment used, variables measured, and indices calculated can be found in Appendix E.

3.2.2 CO_2

Measurement of CO_2 at indoor and outdoor locations was accomplished using two different instrument packages. Indoor CO_2 was measured using a HOBO with data logger suspended from the tripod housing the thermal comfort instrumentation. Initially, outdoor CO_2 was measured using a Bacharach sensor placed outdoors away from an entrance, but under an overhang to protect it from the weather. Indoor and outdoor CO_2 was collected during the same time periods that thermal comfort was collected indoors. Summary of the protocols for the HOBO and the Bacharach instrumentation used in the office buildings are listed in Appendix F. However, the BACHARACH meter failed during initial data collection. Prior to the failure, the data were questionable compared to HOBO CO_2 meters, so the BACHARACH was no longer utilized. Instead, one IAQRAE (see VOC section below) was used to measure outdoor CO_2 concentrations. The HOBOs attached to each thermal comfort station were used to measure indoor CO_2 concentrations in each indoor location. The indoor to outdoor CO_2 differential concentration was then calculated for each location by deducting outdoor CO_2 concentration from the indoor CO_2 concentration at each station.

3.2.3. VOCs

Air samples for VOCs were collected for a discrete time period at the same six indoor locations as the airborne culturable and total fungal spore samples using the RAE Systems' IAQRAE 042-1211-012 with Calibration kit according to the manufacturer's protocol. Summary of the protocol used is listed in Appendix G.

3.3 AIRBORNE AND SURFACE-ASSOCIATED MOLD

Measurements of airborne and surface-associated mold were determined using commercially available instrumentation routinely used in the field (Buttner et al., 2002b) and traditional culture-based or microscopic assay as appropriate. Protocols for sample collection, processing, and analysis are listed in Appendix H. All samples for airborne and surface-associated mold were collected indoors in proximity to the six locations where thermal comfort, CO_2, VOC, sound, and lighting measurements were collected. The outdoor air samples were collected in proximity to the CO_2 and VOC sensors. Air samplers were placed on a collapsible cart for transport through the buildings and for consistent height from the floor.

Air samples for culturable fungi were collected using the Andersen single-stage impactor sampler supplied with malt extract agar amended with an antibacterial compound (chloramphenicol). Analysis of the samples was conducted by a consultant (Natural Link Mold Laboratory, Sparks, NV). Culturable fungi on the Andersen samples were identified using macroscopic and microscopic morphology. Samples for airborne fungal spores were collected using the Burkard personal impactor sampler. Burkard slides were transported to the UNLV microbiology laboratory for analysis. Vacuum sampling using an individual field filter cassette attached to a vacuum pump was used to sample porous or hard surfaces for

settled particulate. Sampling was conducted on the floor at each indoor location. Each cassette was transported to the consultant laboratory (Natural Link Mold Laboratory) for analysis.

3.4 SOUND

A sound measurement protocol was developed. The protocol was designed to be usable by technicians with a minimum of special training and standard, quality instruments. An analysis method was developed for this study by Verdi Technology Associates to evaluate hypotheses and to determine results of field measurements. The protocol for field measurements includes selection of the testing equipment and procedures to transport, set-up, and disassemble the equipment and capture and retrieve data (**Appendix I**).

3.5 LIGHTING

Five groups of data were collected in this study, including: 1) subjective measures of lighting, 2) photometric and other direct environment measures, 3) lighting power density and other indirect measures, 4) descriptive characteristics of the occupants and 5) other subjective measures not directly related to lighting, but which may influence it. These five groups of data are summarized as follows:

The subjective measures were collected through four categories of questions related to the impressions of satisfaction, performance, attractiveness and appropriateness of the lighting design. In the category of impressions of satisfaction, occupants were asked about ratings of overall satisfaction with the lighting at the work space, how well the building is lit overall, satisfaction with the lighting for different tasks, preference for improved light compared to other possible changes, preference for more daylight compared to other possible changes, and location of ceiling lights in relation to work area. In the second category of questions regarding occupants' impression of performance, questions included ratings of the amount of light for tasks, annoyance with reflected glare, with glare from ceiling lights, task lights, sunlight, and light above or behind a CRT screen, flickering off CRT screens. The third category of questions related to impressions of attractiveness, including ratings of the overall lighting attractiveness, lighting quality, building attractiveness, and visual environment. The last category of questions concerned the impressions of appropriateness of the lighting design, which included the ratings of the appropriateness of light for primary task, secondary task, portions of light source relative to task, opportunity for visual relief, ambient light sources for overall work space and supplementary task light sources.

The optometric and other direct environmental measures related to lighting included illuminances, luminances, contrast characteristics, outdoor sky conditions, and other environmental conditions. Illuminances were measured at primary and secondary task surfaces without and with body shadows, respectively. Luminances were measured at task for standardized white paper, surface immediately surrounding task, ceiling between luminaires, brightest light source in field of view, brightest ceiling area in field of view, darkest area in field of view, walls at eye levels of left, right, and straight ahead, respectively. Information on contrast characteristics of space was collected at a 25° viewing angle normal, 45 left, 45 right to the desk, respectively. Other environmental data included outdoor sky conditions, type of window glazing and window treatment, height of space divider, predominant furnishing treatment used, predominant wall treatment used, colors in workstation, descriptions of supplemental task lamp, and light control switches.

Lighting power density data were obtained indirectly by computing the ratio of the connected power load to the workstation floor area. Other indirect environmental data were also recorded (e.g., floor area, the distance to nearest windows).

Descriptive characteristics of the occupants were collected, including age, gender, professional levels, whether they wore glasses, how long working at the location, and how many hours/days they were in the building.

Other subjective measures not directly related to the visual environment were also collected (e.g., ratings of convenience of commuting to work, annoyance with surrounding noise, comfort with heating, ventilation and cooling systems, frequency of health problems).

The measurement protocols used (Appendix J) were modified during the study for three reasonsL First some information collected did not prove useful (e.g., the measurement of luminances at task for standardized white paper could be eliminated, because it could be derived from illuminance measurements and the reflectance of standardized white paper). Second, the color characteristics of the building lighting were collected, which had not appeared in any previous field survey. Third, one of the objectives of the project was to develop lighting survey protocols as part of integrated building monitoring protocols (e.g., can be easily used by others, thus the lighting protocols used in our study were less complicated).

The surveyor manually recorded the physical measurements and environmental conditions in the lighting survey table (**Appendix K**). The table included six sections of data: room descriptions, lighting and control system types, luminaire information, lighting power density, measurements of workstation, and luminance of room surfaces and window surfaces.

In the first section, room descriptions, information on location, area, height, window availability, daylighting control means, and whether computers were present were recorded. Field surveyor also recorded any lighting-related special issues in the space provided under the note item.

In the second section, lighting and control system types, ambient lighting and task lighting systems were selected from multiple choices. The choices were from common systems used in office lighting.

The third section, luminaire information, was used to record information regarding the number, voltage, wattage, mounting height, light source and color properties for ambient and task lighting, respectively. An office space normally has only one type of ambient lighting system and one type of task lighting system. However, the table can record up to 3 different types of ambient lighting and task lighting, in case more systems were used in surveyed buildings.

In the fourth section, Lighting Power Density (LPD) was estimated. The LPD was obtained by two different means in the survey. One was by seeking information from building facility mangers or building owners. However, in most cases, they could not provide the LPD information. Therefore, the second method was more often used, which was to compute the ratio of the total installed power of luminaires, for both ambient lighting and task lighting, to the floor area. The surveyor tried to obtain the information on lighting systems, including lamps and ballasts, from the building facility managers. However, if the information was not available, the surveyor would count the number of lamps and luminaires in the space and observe lamp information in the field. Then, the total installed power was computed by assuming zero ballast losses. The floor area of the room was either directly measured with an ultrasonic measuring tool, or calculated from drawings. With information on the total installed power and floor area, LPD could be computed. In this study, LPDs were computed for an entire office building, not for different rooms in the building, so each building had only one LPD value.

The fifth section, measurements of workstations, included the measurements of illuminance, luminance and color properties of multiple locations. Illuminances were measured with Minolta illuminance meter T-10, while luminances were measured with Minolta luminance meter LS-100. Illuminances on the work surfaces, source documents of computer work, computer screens, and floors were measured. Luminances were measured for ceilings between luminaires, the brightest light source in field of view, brightest ceiling area in field of view, darkest partition area in field of view, wall and partitions surrounding the workstations, brightest area of the sky from the window, a nearby building from the windows and floors. In addition, spectral power distributions (SPDs) of the lighting at work surfaces were measured with

GretagMacbeth Lightspex spectrometer, and chromaticity coordinates, color rendering index and correlated color temperature were derived from the measured SPDs.

Illuminance and luminance measurements are very sensitive to locations and directions, which is very different from other environmental measures. For example, temperature and sound pressure level sensors are omni-directional and their measurements do not vary much within the space of a workstation. However, with even as little as one inch or 5° (angle) of difference, two measurements of illuminances and luminances can be significantly different. This difference is caused by the intrinsic characteristic of lighting distribution, which is normally not very uniform over a surface and space. Therefore, the decisions of illuminance and luminance measurement locations in lighting surveys are quite challenging, and depend greatly upon the surveyor's lighting knowledge and survey experience.

Lighting was measured for six workstations each day, a total of 18 workstations for each building in three days. This decision was made because lighting measurements are intrinsically different from other environmental measurements in that they are discrete measurements on multiple points, not continuous readings on one point. In addition, monitoring one workstation three times does not provide as valuable a database as monitoring three different workstations. As a result, 18 workstations were measured for each building in this study, among which six workstations were the same as for the other measurements. The other 12 workstations were spread throughout the building, with two in each zone. Six workstations were monitored each day, with the measurements spaced through the day.

The lighting data were recorded manually and then entered into the database through a data entry tool. Manually recording into a table was the most convenient way to deal with the lighting measurements, because the lighting data were discrete and taken at multiple locations with different instruments.

The Building Sciences Database was designed to store the data obtained in the task, and can be efficiently reused, easily expanded and aggressively searched at **www.ncembt.org**.

4. RESULTS

4.1 BUILDING LOCATIONS

Figure 1 depicts the locations of the selected office buildings overlayed on the International Energy Conservation Code Climate Zones Map.

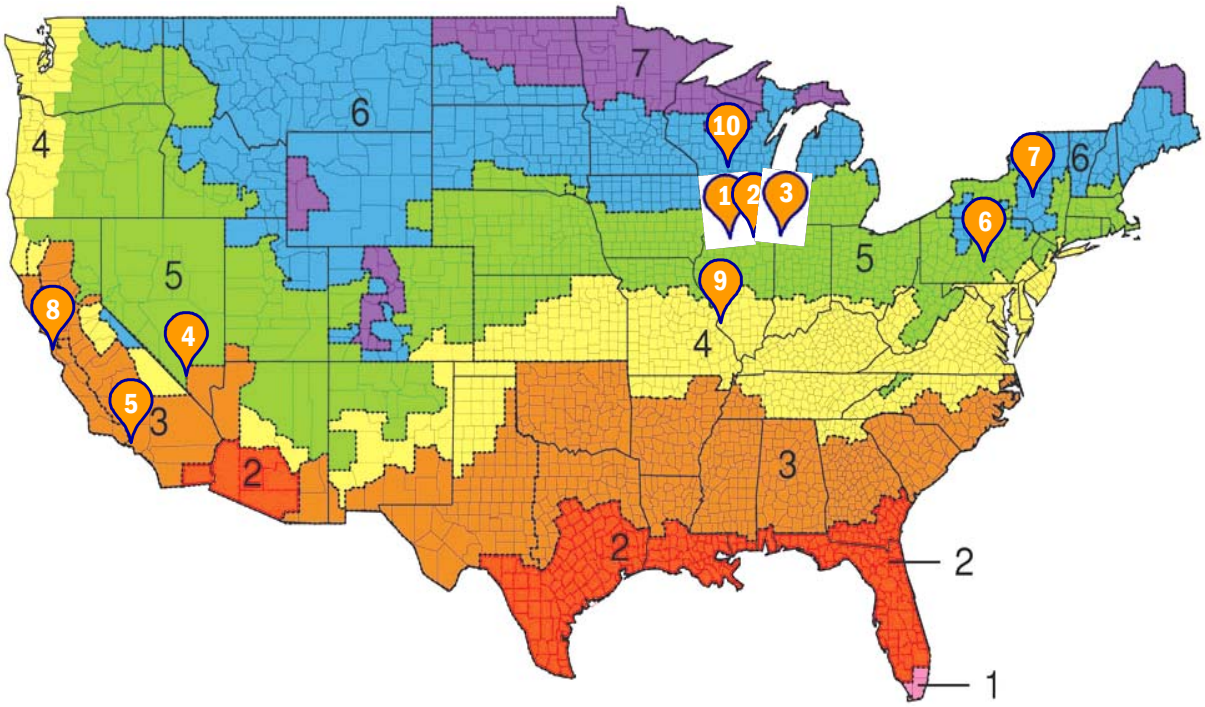

Figure 1. International Energy Conservation Code Climate Zones Map and Locations of Monitored Buildings

4.1 ENERGY TABLE

Available information gathered from the building's facilities manager detailing the energy usage and costs are compiled in Appendix L.

4.2 OVERVIEW OF RESPONSES

Figures 2 through 11 depict the overview of responses of building occupants to the acceptability of IEQ (i.e., temperature, relative humidity, draft), odors, sound, and lighting. Specific measurements collected during monitoring and responses of occupants are presented in Section 4.3 through Section 6.4.

The IEQ questionaire was submitted electronically and occupants could complete it any time during the monitoring period.

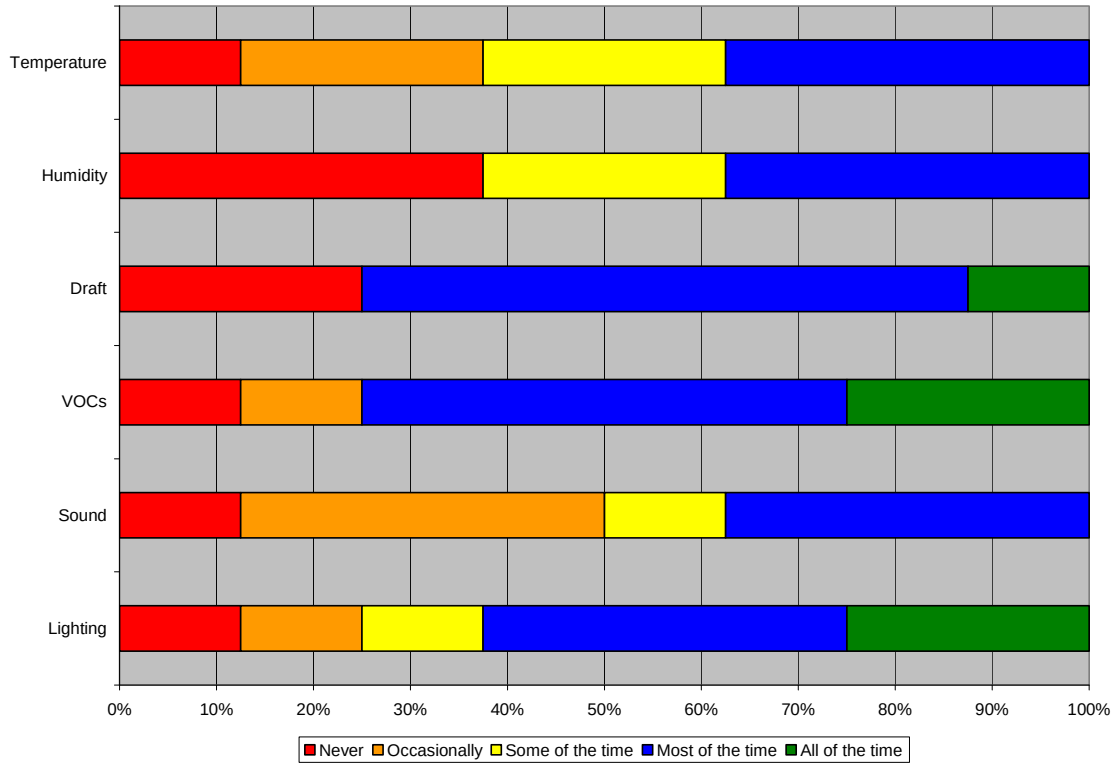

Figure 2. Building 1: Summary of occupant responses to the perception questionnaire for acceptability of IEQ (temperature, relative humidity, draft), volatile organic compounds (VOCs), sound and lighting.

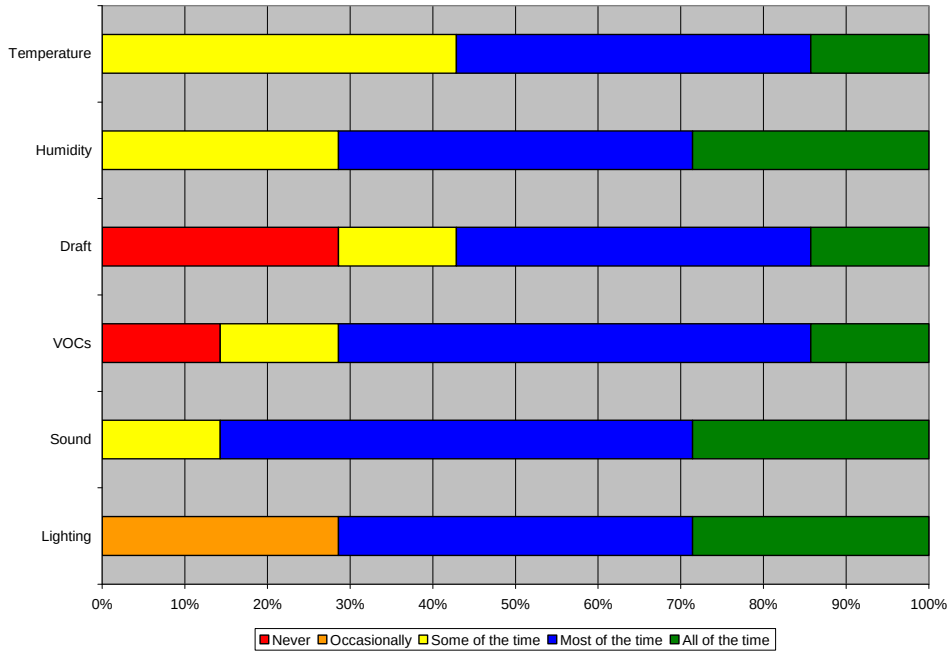

Figure 3. Building 2: Summary of occupant responses to the perception questionnaire for acceptability of IEQ (temperature, relative humidity, draft), volatile organic compounds (VOCs), sound and lighting.

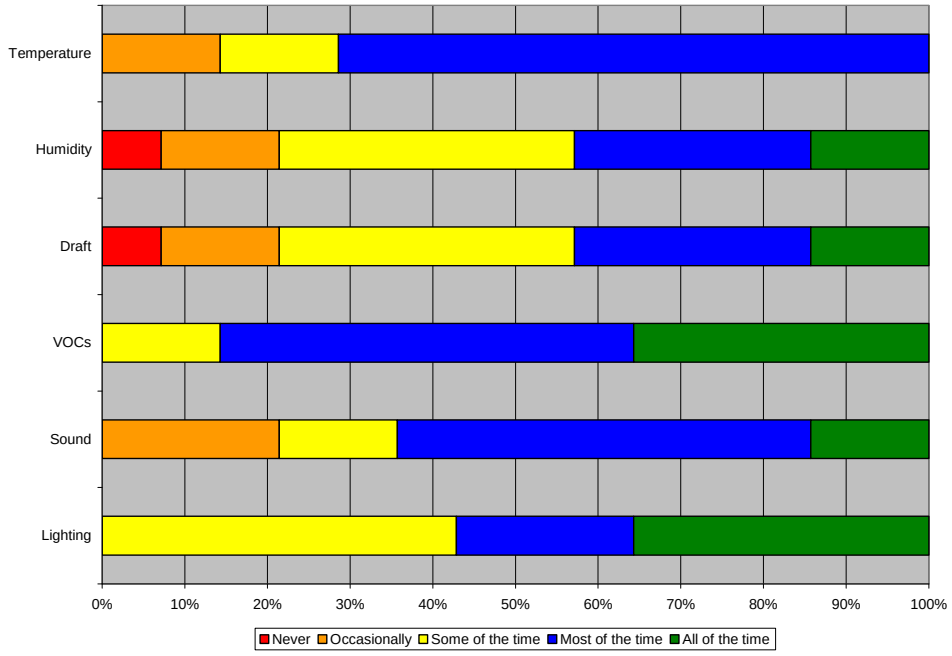

Figure 4. Building 3: Summary of occupant responses to the perception questionnaire for acceptability of IEQ (temperature, relative humidity, draft), volatile organic compounds (VOCs), sound and lighting.

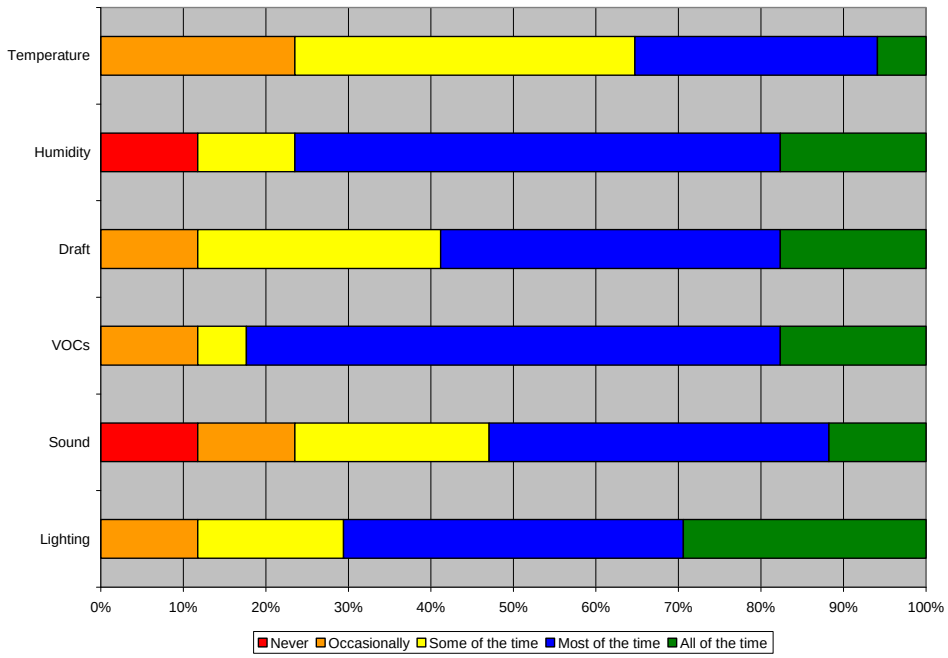

Figure 5. Building 4: Summary of occupant responses to the perception questionnaire for acceptability of IEQ (temperature, relative humidity, draft), volatile organic compounds (VOCs), sound and lighting.

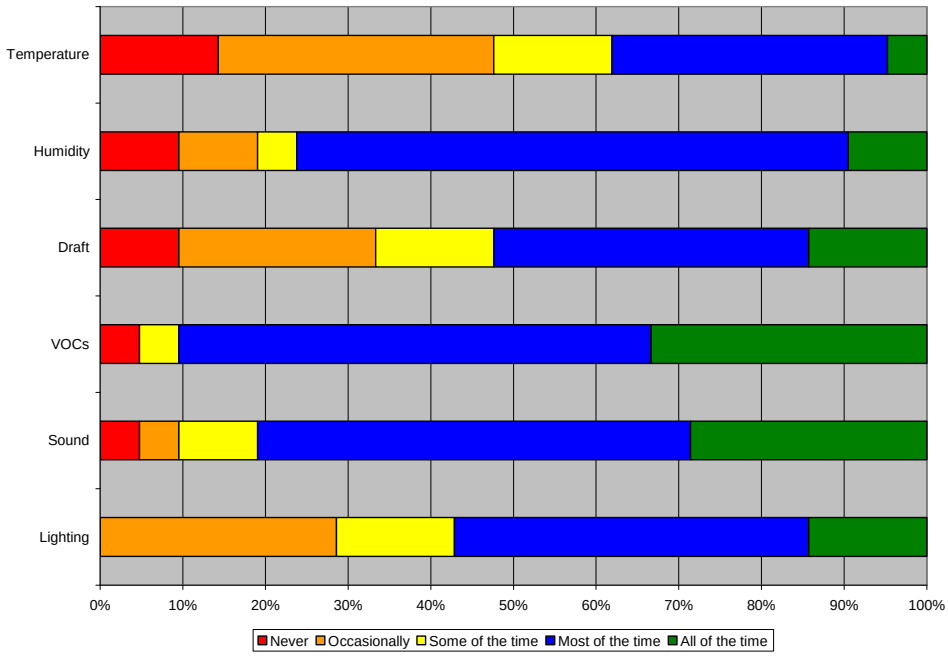

Figure 6. Building 5: Summary of occupant responses to the perception questionnaire for acceptability of IEQ (temperature, relative humidity, draft), volatile organic compounds (VOCs), sound and lighting.

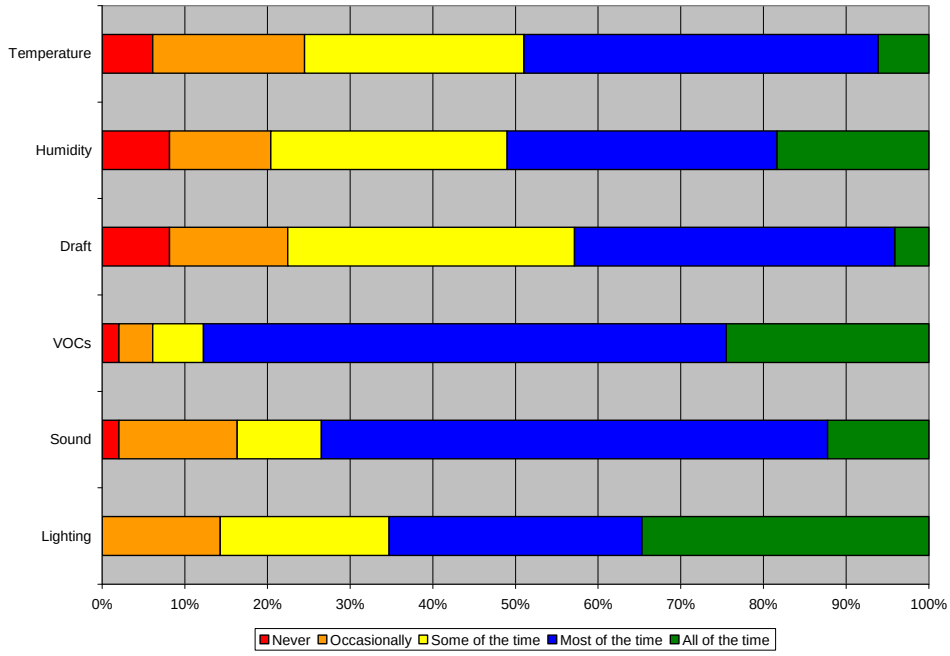

Figure 7. Building 6: Summary of occupant responses to the perception questionnaire for acceptability of IEQ (temperature, relative humidity, draft), volatile organic compounds (VOCs), sound and lighting.

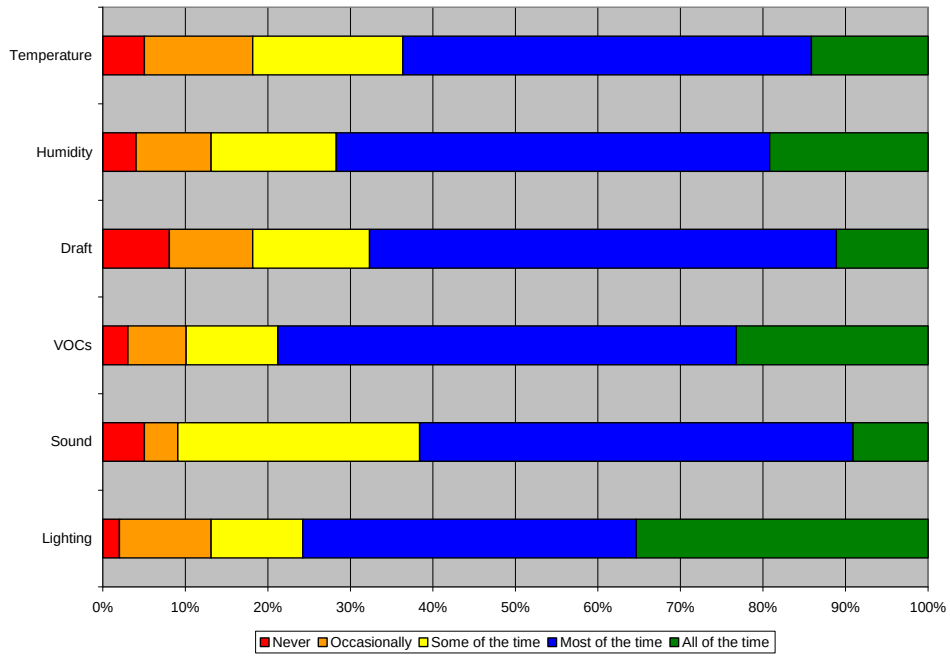

Figure 8. Building 7: Summary of occupant responses to the perception questionnaire for acceptability of IEQ (temperature, relative humidity, draft), volatile organic compounds (VOCs), sound and lighting.

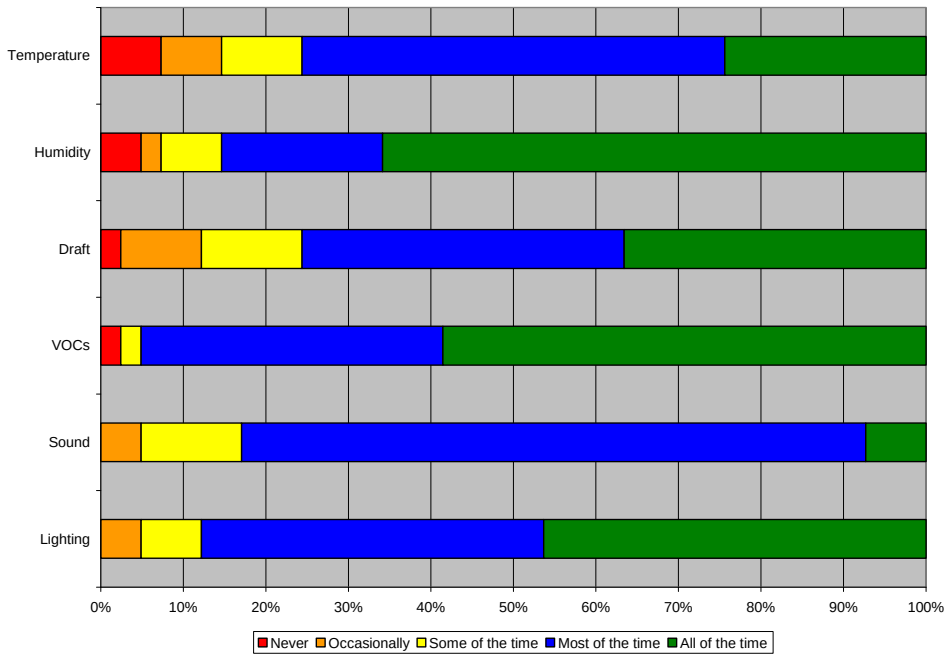

Figure 9. Building 8: Summary of occupant responses to the perception questionnaire for acceptability of IEQ (temperature, relative humidity, draft), volatile organic compounds (VOCs), sound and lighting.

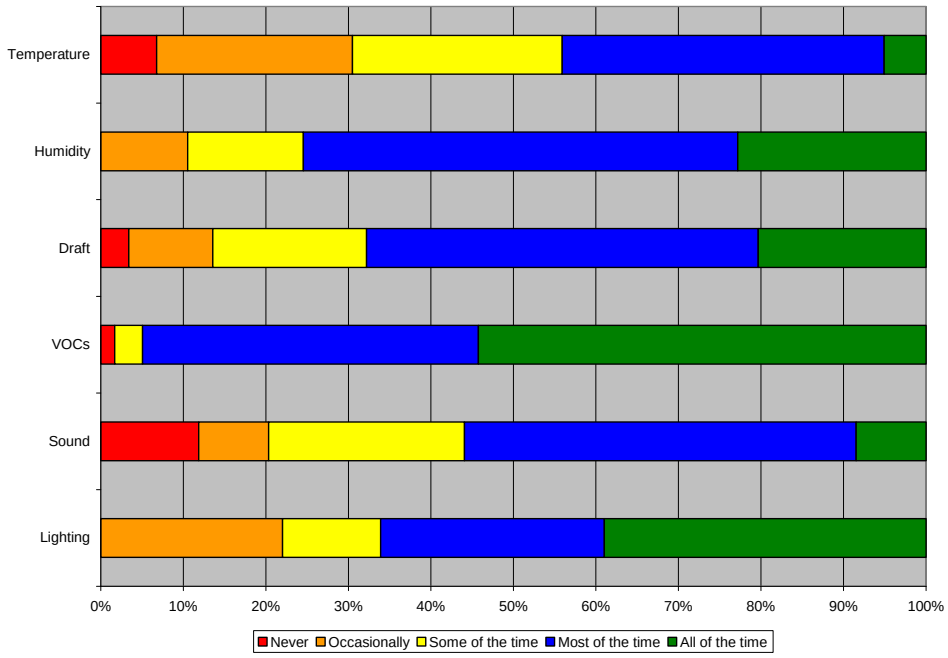

Figure 10. Building 9: Summary of occupant responses to the perception questionnaire for acceptability of IEQ (temperature, relative humidity, draft), volatile organic compounds (VOCs), sound and lighting.

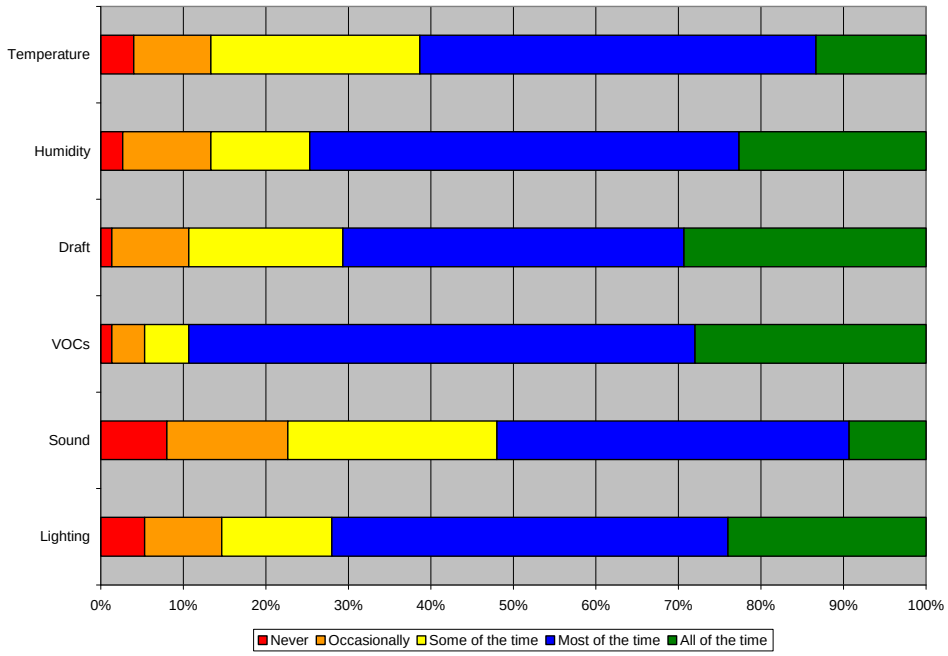

Figure 11. Building 10: Summary of occupant responses to the perception questionnaire for acceptability of IEQ (temperature, relative humidity, draft), volatile organic compounds (VOCs), sound and lighting.

4.3 THERMAL COMFORT/IEQ

Results of the IEQ portion of the occupant questionnaire by building are in Appendix M. Results of the hypotheses test results are shown below.

4.3.1 IEQ Hypotheses Results

IEQ Hypothesis #1: > 80% of occupants in a building will be thermally comfortable if: 27°C ≥T_o ≥24°C (summer) and 24.5°C≥ T_o ≥20°C (winter)] and 0.012 ≥ W ≥ 0.0032 kg of water/kg of dry air.

Null Hypothesis

< 80% of occupants in a building will be thermally comfortable if: 27°C ≥T_o ≥24°C (summer) and 24.5°C≥ T_o ≥20°C(winter) AND 0.012 ≥ W ≥ 0.0032 kg of water/kg of dry air.

Test Results

One building (Building 8) had an "Env(ironment)Accept(ance)" rating of 81% and its average temperature and humidity fell within the confort range recommended by ASHRAE Standard 55-2004.

Interpretation and Comments

Temperature is perceived as acceptable by a majority of respondents in all buildings. Based on average values of temperature and humidity, only 6 of the 10 buildings were within the ASHRAE measurement criteria for thermal acceptability. There is limited inter-zone variability in the perception of thermal comfort, which does not appear to be consistently related to variables such as frequency of air conditioning, heating, or ability to control or know the value of the temperature. None of the buildings has both measured conditions and occupant responses to thermal comfort that meet the ASHRAE thermal comfort criteria. Also, in all but two buildings (Building 8 and 10) the questionnaire participation rates are so low that they cannot be considered representative of the entire building population. In these two buildings, acceptability approached 80%; however, they did not meet the winter ASHRAE temperature criteria. Those two buildings also have the overall highest workplace environment acceptability ratings, which may or may not bias the responses to thermal acceptability.

There are insufficient data to support or refute the null hypothesis.

IEQ Hypothesis #2: There is a significant difference between mornings and afternoons in thermal perception by occupants.

Null Hypothesis

There is no significant difference between mornings and afternoons in thermal perception by occupants.

Test Results

In all buildings, most (mean 74%) occupants report that the temperature does not fluctuate frequently between AM and PM. Most respondents report that the temperature in the AM and PM (83% and 84%, respectively) does not reach the extremes of too cool or too warm. In contrast, almost 1/3 (mean 31%) of respondents reported that the building is frequently too cool at least some part of the day. There is a statistically significant correlation in perceived temperature acceptability and actual differences in morning vs. afternoon average (least squared mean) temperatures in Buildings 5 and 8 only. Among the questionnaire variables tested in this hypothesis, knowing the temperature has the most consistent correlation (Buildings 1, 7, 9, and 10) with actual AM vs PM temperature differences.

Interpretation and Comments

Temperature fluctuation between AM and PM is not problematic in the population of buildings studied. Perception of temperature acceptability correlates with this minimal actual temperature AM/PM fluctuation in only two buildings (Buildings 5 and 8), one of which (Building 8) has significant inter-zone variability among respondents. The lack of consistent correlations is likely due to the relatively low number and percentage of occupants in each building who perceive a temperature fluctuation problem. There are significant but inconsistent correlations between the other questionnaire variables for various buildings, which may be due to chance and/or low questionnaire participation rates.

There are insufficient data to support or refute the null hypothesis.

IEQ Hypothesis #3: ≤10% of occupants will make adjustments to their work area to make it more thermally comfortable.

Null Hypothesis

>10% of occupants will make adjustments to their work area to make it more thermally comfortable.

Test Results

Questionnaire question on the ability to control the temperature themselves indicates an average of 21% (range 5-49%) of respondents are able to control the temperature via a thermostat. In three buildings (Buildings 1, 2, and 3) no occupant can control the temperature via the thermostat. Responses to knowing the temperature shows that an average of 82% of respondents cannot determine the specific temperature in their work area by reading a thermostat. The response questions to the temperature being too cool or too warm demonstrate that only a small percentage of occupants adjust the thermostat (2% and 14%, respectively) in response to unacceptable temperature conditions. Very few respondents use a space heater or fan in response to uncomfortable temperature conditions. The only personal response observed among a significant percentage (mean 51%) is to put on clothing in response to temperature being too cool. The proportion test corroborates that fewer than 10% of respondents make adjustments for thermal comfort.

Interpretation and Comments

In most buildings where occupants can adjust the temperature themselves via thermostat, <10% do so in response to temperature too cool, whereas the proportion approached 10% in response to too warm. However, there are inconsistencies in the responses to these questions in the three buildings where occupants report they cannot control the temperature themselves.

There are insufficient data to support or refute the null hypothesis.

IEQ Hypothesis #4: If the occupants' work areas are thermally unacceptable, the occupants in that area will work less efficiently (i.e., less productively).

Null Hypothesis

If the occupants' work areas are thermally unacceptable, the occupants in that area will work more efficiently (i.e., more productively).

Test Results

For the question concerning temperature being to cool and affecting their work, only an average of 7% of respondents report that their productivity is adversely affected most or all of the time; 23% are affected some of the time. For temperature being too warm and affecting their work, these values are 2% and 31%, respectively. Kruskal-Wallis and Chi Square tests show that there are only two buildings where there is significant inter-zone variability in responses to work affect questions (Buildings 1 and 3), neither of which has significant variability in overall temperature acceptability and both of which have very low questionnaire participation rates. In Building 1 where there is significant inter-zone variability for productivity from too warm and too cold, there is corresponding inter-zone variability in the range of desirable thermal conditions, though in this building the participation rate was very low. Correlation between acceptable temperature and the various temperature perception questions shows significant correlations to liking the

temperature (Buildings 2, 6, 8, 9 and 10), frequency of heat (Buildings 1, 6, 7, 8, 9, and 10) and ai condicioning frequency (Buildings 1, 7, and 10) in multiple buildings, but only to temperature affecting their work in Building 2 (Pearson correlation only) and Building 7 (Spearman correlation only; both with low questionnaire participation rates) and to knowing the temperature (Building 4).

Interpretation and Comments

The prevalence of adverse work productivity perception is relatively low compared with perception of overall perception of thermal acceptability. There is minimal inter-zone variability in perceived work productivity impacts related to thermal acceptability in all of the buildings studied. In comparison to responses to overall thermal acceptability, there is a disproportionately lower percentage of respondents who report that thermal unacceptability frequently affects work productivity. Low questionnaire participation rates likely account for some false positive findings. Perceived thermal unacceptability does not correlate with perceived lowered work productivity in most buildings.

The null hypothesis is not supported.

IEQ Hypothesis #5: The occupants of a building will be thermally comfortable if the vertical temperature gradient is ≤3.0 °C.

Null Hypothesis

The occupants of a building will not be thermally comfortable if the vertical temperature gradient is ≤3.0 °C

Test Results

All 10 buildings have an average vertical temp gradient <3.0C. For the questions asking about where the occupant feels too cold and too warm, the most prevalent response is "all over my body" (43% and 58%, respectively). Correlation analysis shows a statistically significant correlation between acceptable temperature and where the temperature feels too warm in Buildings 1, 3, and 8; and with where the temperature feels too cold in Buildings 1 (Spearman correlation), 2 (Pearson correlation), 3 (Pearson correlation), and 8. Buildings 1 and 3 may be false positives due to low questionnaire participation rates.

Interpretation and Comments

Vertical temperature gradients are within the acceptable level in all buildings. Thermal acceptability is not associated with perception of thermal discomfort in a particular body part. Perceived thermal unacceptability is correlated with a particular body part in only a minority of buildings, two of which had very low questionnaire participation rates.

The null hypotheses is not supported.

IEQ Hypothesis #6: There is a significant difference between mornings and afternoons in relative humidity and related occupant comfort perception.

Null Hypothesis

There is no difference between mornings and afternoons in relative humidity and related occupant comfort perception.

Test Results

Occupant perception of humidity shows that a majority of occupants find the humidity acceptable most or all of the time (mean 70%, range 43-85%) in all buildings. Conditions are rated as neither too humid nor too dry amongst nearly all respondents (96% and 96%, respectively). Only a small percentage of respondents rate the office environment as too dry (11%) or too humid (2%) during some part of the work day. A majority (95%) of respondents do not report frequent fluctuations in perceived humidity/dryness. Correlation analysis shows that changes in perceived humidity between morning and afternoon do not correlate with actual AM-PM measured humidity differences within any buildings or among buildings. Changes in perceived humidity correlate with AM-PM measured temperature differences only in Building 1, but amongst all buildings there is no significant correlation.

Interpretation and Comments

Most occupants report perceived humidity as acceptable most or all of the time in all buildings. Fluctuations in humidity are uncommon. Perceived changes in humidity from morning to afternoon do not correlate with actual measurements of humidity or temperature in most or all buildings. The latter may be due to minimal changes in actual humidity (i.e., a small range) and/or the low prevalence of respondents who report humidity-related problems. Perception questionnaire data from Building 1 should be considered circumspect because the questionnaire participation rate was very low.

The null hypothesis is supported.

IEQ Hypothesis #7: ≤20% of occupants will make adjustments to their environment when they are in a too dry (AH<0.0032 Pa) or too humid environment (AH>0.012 Pa).

Null Hypothesis

>20% of occupants will make adjustments to their environment when they are in a too dry (AH<0.0032 Pa) or too humid environment (AH>0.012 Pa).

Test Results

Of the relatively small proportion of respondents who report conditions too dry or too humid, the vast majority do not respond by adjusting their environment. The proportion test shows that in all the buildings, <20% of occupants make any type of adjustment to excessively dry or humid conditions. The most prevalent perception questionnaire responses are applying moisturizer when too dry or removing clothing when too humid. Kruskal-Wallis and Chi Square analysis shows significant inter-zone variability for perception of s"too dry" in all responses for Building 1 only. For responses of "too hot" only adjusting the thermostat, opening/closing a door, or leaving are significant for Building 1. Building 1 is one of only two buildings that falls below the acceptable minimum humidity level.

Interpretation and Comments

All but two of the buildings fall within the target humidity range. Most occupants in all the buildings do not report conditions too dry or too hot; of those who do, most do not make adjustments. Inter-zone variability in making adjustments is limited to one building (Building 1), which had a mean humidity below the target range, but which also had a very low questionnaire participation rate which may have produced a false positive result(s).

The null hypothesis is not supported.

IEQ Hypothesis #8: <15% of building occupants should feel a draft anywhere if the draft rate is ≤15%. If the draft rate is ≤15%, ≥80% of occupants in a building should feel comfortable.

Null Hypothesis

>15% of building occupants should feel a draft anywhere if the draft rate is ≤15%. If the draft rate is ≤15%, <80% of occupants in a building should feel comfortable.

Test Results

The average draft rate exceeds 15% in two buildings (Building 4 and 7). A mean of 64% of respondents report perceived draft as acceptable most or all of the time. In two buildings (Building 3 and 6) a majority of respondents rated the draftiness as unacceptable. 10 of 10 buildings have respondent rates >20% for draft non-acceptability. The mean rate of feeling a draft during some part of the work day is 17% (range 13-27%), with "often drafty" (most work days or every work day) >20% of respondents in 3 buildings (Building 3, 4, and 8); note low respondent rates in the first two buildings). An average of 99% of occupants prefer the air neither drafty nor stagnant (an expected finding). Kruskal-Wallis but not Chi Square analysis shows significant inter-zone variability in responses to the question of too drafty in Buildings 3, 4, and 7; Draft acceptability shows significant inter-zone variability in Building 1, 2, 3, 4, 6, and 8.

Interpretation and Comments

Most buildings have an average draft rate that is <15%. A majority of respondents find draft acceptable, and in the two buildings where a majority of respondents report draft unacceptability, the measured draft rates are within the acceptable criterion. There is some inter-zone variability in reporting of draftiness; however, low questionnaire rates may explain some of this. In addition, large standard deviations in draft measurements may reflect intermittent draftiness that affects respondents' responses to these questions in some zones within buildings. The significance for KruskalWallis but not Chi Square is not surprising, given that Chi Square is looking for a much less specific difference (a different profile of responses, rather than a skewed distribution of responses).

There are insufficient data to support or refute the null hypothesis.

IEQ Hypothesis #9: Occupants will make adjustments to their environment to reduce the presence of a draft in their work environment.

Null Hypothesis

Occupants will not make adjustments to their environment to reduce the presence of a draft in their work environment.

Test Results

The questionnaire responses show that of those respondents who perceive draft problems, the percentage who make no adjustments in the work environment is very high in every building: register (94%); door (100%), complains/reports (98%) or mentions (88%) the problem, leaves (97%) or perceives an adverse impact on work productivity (94%). The proportion test shows that the proportion of respondents who make adjustments is statistically significantly >20% for questions concerning draft from the register (no buildings) draft closing a door (Building 1); reporting the draft (no buildings); mention the draft (no buildings); and leave the area because of draft (Building 6). The lack of significance in other buildings is likely a reflection of a small occupant response rate. The Kruskal-Wallis/Chi Square tests show significant inter-zone variability in all adjustments for Buildings 2, 3, 4, 7, and 8 (except for leaving the area due to draft Building 8). Correlation analysis does not demonstrate a consistent correlation between draft rates (at the three heights measured) and various responses to the questionnaire, including the various adjustments to the environment to reduce draft, and perceived impact on work productivity. In the two buildings (Building 4 and 7) with high average draft rate, almost no significant correlations are observed. Building 1, in which the average draft rate was well below 15%, has multiple, statistically significant correlations with adjustments. However, the questionnaire participation rate was exceedingly low in this building, making the results of questionable significance. Building 10 is the only building with consistent correlations between questionnaire questions and draft, defined as >15% for any of the 3 draft height measurements.

Interpretation and Comments

Although draft unacceptability is higher than postulated, most occupants do not respond to the problem by making adjustments, nor do most perceive it as having an adverse impact on work productivity. No single building shows a consistent pattern of having occupants making adjustments to address draft. In some buildings, there is significant zone-to-zone variability in occupant adjustments, though the overall rate of such adjustments (as obtained via the perception questonnaire) is relatively low. An elevated average measured draft rate does not appear to consistently correlate with occupant responses regarding drafty conditions, adjustments to the environment, or perceived impact on productivity in most of these buildings.

The null hypothesis is supported.

IEQ Hypothesis #10: ≥80% of occupants in a work area (zone) will not complain of stuffy air if the indoor vs. outdoor concentration difference in CO_2 ≤ 700 ppm.

Null Hypothesis

<80% of occupants in a work area (zone) will not complain of stuffy air if the indoor vs. outdoor concentration difference in CO_2 ≤ 700 ppm.

Test Results

A majority of occupants (mean 73%) find the freshness of their work environment acceptable. A mean of 89% report stuffiness infrequently, with high consistency among buildings. Kruskal-Wallis/Chi Square tests show significant inter-zone variability in Buildings 1 and 3 for the response of liking the air as it is; Buildings 1, 2, 3, 5, 6, and 7 for the response of too stuffy; and no significant variability for answers to having an air purifier. The proportion test for the response of too stuffy shows that the dissatisfaction rate is <20% for 7 of the buildings with Buildings 1, 5, and 6 the exception. The difference in outdoor-indoor CO_2 average concentrations is <700 for all buildings except Buildings 6 and 7. However, the responses of acceptable and too stuffy as unacceptable were not larger in these buildings than in other buildings with outdoor-indoor CO_2 differences <700.

Interpretation and Comments

Most respondents find the air in the work environment acceptably fresh and infrequently stuffy. The outdoor-indoor CO_2 difference is within the ASHRAE range for all but two buildings. There is significant inter-zone variability in perception responses for five of the buildings. The indoor - outdoor CO_2 differences are not consistent with occupant perception responses for buildings with significant differences (>700 ppm) in mean CO_2 concentrations.

The null hypothesis is supported.

IEQ Hypothesis #11: ≤20% of occupants who perceive the air is stuffy or stagnant will make adjustments to their work environment to make their work area more comfortable.

Null Hypothesis

>20% of occupants who perceive the air is stuffy or stagnant will make adjustments to their work environment to make their work area more comfortable.

Test Results

Among respondents who perceive air as stuffy (56%), the majority infrequently adjust their thermostat, use a fan, open or close a door, or leave the area. Kruskal-Wallis/Chi Square tests shows significant intra-building variability in responses for using a fan and leaving the room in Buildings 1 and 2.

Interpretation and Comments

Of those respondents perceive the air as being stuffy at least some portion of the work day, nearly all do not make adjustments to their workplace to address the problem.

These findings do not support the null hypothesis.

IEQ Hypothesis #12: If the occupants' work areas perceive their air as stuffy or stagnant, the occupants in that area will work less efficiently (i.e., less productively).

Null Hypothesis

If the occupants perceive their work areas air as stuffy or stagnant, they will work more efficiently (i.e., more productively).

Test Results

Among respondents who perceive air as stuffy (56%), the majority are not frequently affected in terms of work productivity. Correlation is significant between indoor-outdoor CO_2 concentration and each of the following questionnaire responses: acceptable fresh air (Buildings 2 and 9), like it as it is (no buildings), air is too stuffy (Buildings 1, 2, 3, and 5), and freshness of the air effects their work (Building 1 and 3).

Interpretation and Comments

Air stuffiness does not appear to significantly impact work productivity. CO_2 concentrations do not consistently correlate with responses to perception questionnaire regarding acceptability of workplace air freshness or impact on work productivity. Fresh air being too stuffy correlates with CO_2 in four buildings, all of which have low perception questionnaire participation rates.

The null hypothesis is not supported.

IEQ Hypothesis #13: If occupants smell unpleasant odors in their work area, no more than (≤) 20% will be uncomfortable and make adjustments in their environment to reduce the odor.

Null Hypothesis

If occupants smell unpleasant odors in their work area, >20% will be uncomfortable and make adjustments in their environment to reduce the odor.

Test Results

Preception questionntaire responses shows that the vast majority of occupants (87% mean) rate the smells as acceptable all or most of the time. An average of 49% of respondents (range 29-73%) never notice odors. Of the 199 of 390 total respondents (51%) who do notice odors, food odors comprise the single, largest category (32% mean), consistently across all buildings. Musty odors are rarely (2%) reported. Across all buildings, odors are infrequently noticed, unpredictably and/or sporadically, without a consistent AM vs PM vs all day pattern. Fewer than 10% of respondents in any building have symptoms (e.g., sneezing, blowing nose) or respond to odors frequently. An average of 5% of respondents report that odors frequently affect their work productivity. Kruskal-Wallis/Chi Square analysis shows that none of the odor response questions varies significantly from zone to zone within buildings. This latter finding may be due to the relatively small numbers of respondents who report any response to odors.

Interpretation and Comments

Nearly all occupants of this set of non-problem buildings do not report frequent odors. Of those who do report odors, food odors are consistently the most frequent type of odor. No consistent temporal pattern of odor observation is reported. Few occupants experience adverse effects or respond to odors. Work productivity is affected in only a small minority (average 5%) of occupants; when buildings with low perception

questionnaire response rates are eliminated, this rate is even lower. Response to odors does not vary from zone to zone within all of the buildings.

The null hypothesis is not supported.

IEQ Hypothesis #14: ≥80% of occupants will have job satisfaction when the indoor environmental quality is acceptable.

Null Hypothesis

<80% of occupants will have job satisfaction when the indoor environmental quality is acceptable.

Test Results

Kruskal-Wallis/Chi Sqare shows that there is significant inter-zone variability in response to the questionnaire asking about having a rewarding job in Buildings 1, 6, 7, and 9.

Interpretation and Comments

This analysis was omitted because the perception questionnaire response rates are so low.

4.3.2 IEQ Summary

The hypotheses were tested and useful results were obtained. The IEQ data analysis completed found some correlation between the IEQ data (i.e, temperature, humidity, draft, vertical temperature and CO_2 difference) and the corresponding questionnaire querry by zones. Some inter-zone variability was also found. However, correlating the IEQ data to the corresponding questions by zone, has the following weaknesses:

- Lack of correlation between the measured data and corresponding perception responses: Only one IEQ measurement station was in each zone. Therefore, it may not be representative of actual prevailing conditions in that zone. This is especially true for draft data because the velocity variation is so high. However, the zone defined in this project is a geometrical zone, which may cover several air conditioning zones which have their own thermostats in big buildings. The respondents who participated in tie questionnaire may not stay in or nearby the office (cubicle) where the IEQ station located. In most cases, the IEQ station was located in an office (cubicle) where there was no occupant. Therefore, there was no occupant in that office (cubicle) to participate in the questionnaire.
- Narrow data range: The variations of measured IEQ data within a building surveyed are small for all the parameters except draft. Such a small variation makes it hard to build a correlation between measured parameters and their corresponding perception responses.

4.4 AIRBORNE AND SURFACE-ASSOCIATED MOLD

4.4.1 Mold Results

Summary statistics were performed by Verdi Technology Associates and UNLV statisticians. Data are illustrated in a series of figures for air and surface mold measurements in Appendix N. Statistical tables for analyses of these measurements are listed in Appendix O.

The percentage of buildings in which airborne culturable fungi were isolated is illustrated in Figure N1. Airborne *Cladosporium* were isolated from 100% of the buildings sampled using the Andersen sampler while airborne culturable *Chaetomium* and *Stachybotrys* were never isolated. Airborne culturable *Trichoderma* was only isolated in Building 7 and *Aspergillus flavus* was only isolated from Building 4 and 6.

The percentage of buildings in which airborne fungal spores were observed using the Burkard non-culturable method is illustrated in Figure N2. Airborne *Aureobasidium*, *Stachybotrys*, and *Trichoderma* spores were not observed in any of the 10 buildings, and *Chaetomium* was only found in one sample from one building (Building 5).

Surface-associated *Stachybotrys* was isolated in 15 of the 180 vacuum dust samples (8%). *Stachybotrys* positive vacuum dust samples were found in at least one sample in eight of the 10 buildings; no positive *Stachybotrys* vacuum samples were found in Building 5 and Building 7. No locations were positive for *Stachybotrys* in dust samples on more than one of the three successive sampling days and at any of the buildings.

4.4.2 Mold Hypotheses Results

Mold Hypothesis#1: In outdoor air, a mixed population of airborne fungus is expected with no one genus except Cladosporium predominating and the distribution of which will vary by geographic region.

Null Hypothesis

In outdoor air samples a predominant fungal taxon other than *Cladosporium* is found.

Test Results

The majority of outdoor air samples demonstrated the presence of a predominant taxon and *Cladosporium* was commonly found as the predominant taxon.

Interpretation and Comment

The null hypothesis is not supported as *Cladosporium* was the predominant taxon in outdoor air samples collected during this study. The study was limited to ten buildings resulting in an insufficient number of buildings that varied by geographic region. Therefore, variation by region was not considered and this was excluded in the null hypothesis.

Mold Hypothesis#2: Among non-problem buildings, a mixed population of airborne fungus is expected with no one genus except Cladosporium predominating and the distribution of which will vary by geographic region.

Null Hypothesis

In indoor air samples a predominant fungal taxon is found and it is not *Cladosporium*.

Test Results

A predominant taxon was only observed in a few air samples, and only Building 6 demonstrated more than 50% of samples with a predominant taxon. The prevalence of *Cladosporium* as the predominant taxon in culturable and non-culturable indoor air samples was low in all buildings. The effect of zone (i.e., zone-to-zone differences) on *Cladosporium* predominance was not statistically significant for either culturable or non-culturable air samples. This was confirmed in logistic regression analyses using "building" as the effect instead of zone. Logistic regression also demonstrated no significant zone effect on whether samples were predominant for culturable air. However, for non-culturable air samples, zone had an effect in one building (Building 7) on predominance. Variance components analysis showed that zone accounted for zero percent of *Cladosporium* predominance variability for culturable air vs. 20% for non-culturable air samples. This is consistent with the findings reported above. The effect of sample date (i.e., day 1 vs day 2 vs. day 3) accounted for 24% of the variability in *Cladosporium* predominance for culturable air samples, but only 7% for non-culturable air samples.

Interpretation and Comments

Among the ten buildings sampled, a finding of mixed populations of mold taxa and/or *Cladosporium* predominance was not consistently found in culturable and non-culturable air samples. *Thus, the null hypothesis is not confirmed*. There was a high degree of consistency within each building between culturable and non-culturable air samples with regard to *Cladosporium* predominance and whether samples showed the presence of a predominant taxon. The effect of zone differences on these parameters was relatively small and the effect of day-to-day sampling variability was more significant for culturable air than non-culturable air on *Cladosporium* predominance. Some of these results may be due to the overall low concentrations which affect the mathematical definition (determination) of rank predominance and mixed populations, as defined for this study. Initially, this hypothesis included the phrase “and the distribution of which will vary by geographic region.” However, due to limitations on the number of buildings (i.e., 10), there were insufficient numbers of building in each region. Therefore, this was excluded in the null hypothesis.

Mold Hypothesis#3: The concentration of airborne fungal genera present in non-problem buildings should reflect the outdoor fungal population in that region.

Null Hypothesis

The airborne fungal genera present indoors in non-problem buildings significantly differ from the outdoor airborne fungal population.

Test Results

As reported above, the majority of outdoor air samples (86%) demonstrated the presence of a predominant taxon and *Cladosporium* was commonly found (55%) as the predominant taxon in outdoor culturable air samples. *Cladosporium* was found as the predominant taxon in fewer non-culturable outdoor air samples. However, *Cladosporium* was the predominant taxon in few indoor culturable or non-culturable air samples. Differences between indoor and outdoor culturable data were statistically significant ($p<0.05$) in four of the 10 buildings; Building 2 (Pearson $p = 0.00$ and Spearman $p = 0.00$), Building 6 (Pearson $p=0.00$; Spearman $p=0.70$), Building 8 (Pearson $p=0.03$), and Building 9 (Pearson $p=0.00$ and Spearman $p=0.01$). Differences between indoor and outdoor non-culturable data were also statistically significant ($p<0.05$) in four of the 10 buildings; Building 1 (Pearson $p=0.01$), Building 4 (Pearson $p=0.01$ and Spearman $p=0.00$), Building 6 (Pearson $p=0.00$, Spearman $p=0.02$), and Building 8 (Pearson $p=0.01$ and Spearman $p=0.01$).

Interpretation and Comment

Statistically significant differences in indoor and outdoor culturable and non-culturable measurements were observed for four of the ten buildings. While *Cladosporium* was commonly found in outdoor air samples, indoors this taxon was rarely observed. *Therefore, the null hypothesis is confirmed*. Originally this hypothesis included the phrase "is dependent on the geographic region." However, due to limitations on the number of buildings (i.e., ten), there were insufficient numbers of buildings in each region. Therefore, this was excluded in the null hypothesis.

Mold Hypothesis#4: The ranges of concentration of airborne total spores observed with non-culturable air sampling and the number of colony-forming units (CFU) of culturable fungal particles isolated with culturable air sampling in non-problem buildings are expected to be similar (<1 order of magnitude, <10X difference) at different sampling locations in the building.

Null Hypothesis

Culturable and non-culturable fungal taxa in air samples collected in non-problem buildings are not similar and will vary by >1 order of magnitude at different indoor sampling locations.

Test Results

Results for both culturable and non-culturable air samples were consistent within or very close to one order of magnitude for the indoor locations (1-6). Logistic regression showed that zone (location) had no effect on concentration ranges for both culturable and non-culturable air samples. Similarly, variance components showed no zone effect. This results from the concentrations being uniform within one order of magnitude for the respective types of air samples within a building.

Interpretation and Comment

The null hypothesis for both culturable and non-culturable air samples is not supported as the results were consistent and did not vary over an order of magnitude in the indoor locations.

Mold Hypothesis#5: The ranges of concentration of airborne total spores observed with non-culturable air sampling and the number of colony-forming units (CFU) of culturable fungal particles isolated with culturable air sampling in non-problem buildings are expected to be similar (<1 order of magnitude, <10X difference) on different days of sampling.

Null Hypothesis

Culturable and non-culturable fungal taxa in air samples collected in non-problem buildings are not similar and will vary by >1 order of magnitude on different sampling days.

Test Results

Results for both culturable and non-culturable fungal taxa in air samples were consistently within or very close to one (1) order of magnitude across the three days of sampling. Statistical analysis demonstrated that there was no difference by sampling day.

Interpretation and Comment

The null hypothesis for both culturable and non-culturable air samples is not confirmed as the results were consistent and did not vary over an order of magnitude between the days of sampling for the majority of the buildings.

Mold Hypothesis#6: Between non-problem buildings, both types of air samples are expected to show the same genera of fungi, with <1 order of magnitude difference in concentration and absence of atypical fungi.

Null Hypothesis

Culturable and non-culturable air samples do not demonstrate the presence of similar fungal taxa.

Test Results

The results for differences in concentration indicate that concentrations are within one order of magnitude for the two types of air samples. As reported above, airborne culturable *Cladosporium* and non-culturable *Cladosporidium* spores were detected in 100% of the buildings. Culturable *Penicillium* species were isolated from 100% of the buildings sampled, but airborne *Aspergillus/Penicillium* spores were only sporadically detected. Airborne culturable atypical (water indicating) *Chaetomium* and *Stachybotrys* were never isolated and spores of these genera were never detected in the non-culturable air samples. However, other atypical fungi were isolated although airborne culturable *Trichoderma* was isolated only in Building 7 and *Aspergillus flavus* was isolated only from Building 4 and 6.

Interpretation and Comment

The null hypothesis is not supported.

Mold Hypothesis#7: Among non-problem buildings, a mixed population of culturable fungi in the surface dust is expected with no one genus except Cladosporium predominating and the distribution of which will vary by geographic region.

Null Hypothesis

In surface dust samples a predominant culturable fungal taxon is found and it is not *Cladosporium*.

Test Results

Cladosporium was isolated from vacuum dust samples in all ten of the buildings and was present in 171 of the 180 samples (95%). *Cladosporium* predominance in surface dust samples varied widely among the ten buildings, but this taxon was often predominant. Logistic regression for zone effect on *Cladosporium* predominance in dust was significant in two buildings (Building 2 and 10) and significant for any predominant taxon in only one building (Building 2). Variance component analysis showed that the building accounted for 21% of the variability in *Cladosporium* predominance, but zone explained very little (7%). However, zone did explain 25% of variability for any taxon predominance. In contrast, sampling date explained very little (8%).

Interpretation and Comment

Cladosporium predominated in surface dust samples in the non-problem buildings and mixed populations were present.

The null hypothesis is not supported.

Mold Hypothesis#8: The concentrations of surface-associated fungal genera present in non-problem buildings are consistent among buildings.

Null Hypothesis

There is no significant difference in the concentration of surface-associated fungal genera between non-problem buildings.

Test Results

Frequency statistics show that the ratio of maximum to minimum culturable fungal concentrations in dust in each building is within 1.5 orders of magnitude, except for Building 8. The standard deviations of these ratios are relatively large compared to the mean in over half the buildings, indicating a wide distribution of concentrations. Logistic regression analysis shows no statistically significant inter-zone variability in dust concentrations in all buildings. Similarly, variance components analysis shows no variability due to zone. The comparison of these data is illustrated in a box and whisker plot in the appendix with the mold statistics tables (**Appendix O**).

Interpretation and Comment

Null hypothesis is generally confirmed with regard to the distribution of concentrations. Some buildings have wider ranges of distributions (max-min) than others. Originally this hypothesis included the phrase "and vary by geographic region." However, due to limitations on the number of buildings (i.e., ten), there were insufficient numbers of buildings in each region. Therefore, this section of the hypothesis was excluded.

Mold Hypothesis#9: The concentration of culturable fungi in non-problem buildings is expected to be ≤10^5 CFU/gram of dust.

Null Hypothesis

Concentrations of culturable fungi in surface dust samples collected in non-problem buildings are >10^5 CFU/gram of dust.

Test Results

Mold summary statistics shows that the proportion (%) of dust samples in each building with total CFU/gm<10^5 varies widely among buildings, ranging from 11% to 61%. Logistic regression analysis demonstrates a zone effect for Building 5 only. Variance components analysis shows that neither zone nor building nor sample day is a significant factor in explaining total dust concentration variability.

Interpretation and Comment

Total dust concentrations <10^5 vary widely within buildings. The zone effect is relatively small on these findings, and sampling date has virtually no effect.

The null hypothesis is not supported.

Mold Hypothesis#10: The range of concentration of surface-associated culturable fungi in dust samples collected in non-problem buildings is expected to be similar (<1 order of magnitude, <10X difference) at different sampling locations in the building.

Null Hypothesis

There is a significant difference in the concentration of culturable surface-associated fungi by location in non-problem buildings.

Test Results

The average ratio of the logarithm of concentrations of fungi cultured from surface dust samples was 1.36 in all but one building (Building 8) where the ratio was less than 1.5 orders of magnitude. There were significantly large outliers which skewed the data. Logistic regression analysis showed no statistically significant inter-zone variability in dust concentrations in all buildings. Variance components confirmed this finding.

Interpretation and Comment

Sample dust concentrations were generally within 1.5 orders of magnitude at different locations within a building. Results showed that in most buildings the range of concentrations is <10^6. The specific effect of different zones did not explain the variability in data among buildings.

The null hypothesis is not supported.

Mold Hypothesis#11: Within the same building at different times of day in the same location, the same genera of fungi are expected to be measured, with up to a 1 order of magnitude difference in concentration.

Samples were only collected at one time period. Therefore, this hypothesis was not tested in the final experimental design used in this task.

Mold Hypothesis#12: Regional differences between non-problem buildings are reflected in the different surface dust composition of fungal genera, not the distribution among them.

Due to limitations on the number of buildings (i.e., ten), there were insufficient numbers of buildings in each region. Therefore, this hypothesis was not tested in the final experimental design used in this task.

Mold Hypothesis#13: "Indicator" fungi (i.e., indicators of water intrusion/moisture accumulation of building materials capable of promoting mold growth) are expected to be "not present" in air samples in non-problem buildings.

Null Hypothesis

Fungi commonly associated with water intrusion will be present in air samples collected non-problem buildings.

Test Results

Neither *Stachybotrys* nor *Chaetomium* were isolated from any of the indoor culturable air samples (Andersen data; **Figure N1**). *Trichoderma* and *Aureobasidium* were isolated, but infrequently and in low concentrations compared to the total concentration of culturable airborne fungi in indoor samples. *Chaetomium* was the only water intrusion taxon observed in the indoor non-culturable samples (Burkard data; **Figure N2**) and it was present as 1% of the observed spores; no *Stachybotrys*, *Trichoderma*, or *Aureobasidium* spores were present in the indoor non-culturable samples. *Aspergillus versicolor* was isolated as 15% of the culturable fungi in 2% of the indoor air samples fungi. *A. flavus* was isolated as 1% of the culturable fungi and *A. niger* was isolated as 4% *Penicillium* spp. were present as >30% of the culturable fungi in 1% of samples, but in the non-culturable air samples, *Aspergillus/Penicillium* spores were never observed as >30%

Interpretation and Comment

Null hypothesis is confirmed for some of the water indicator fungal taxa but marginally as the majority of the taxa were not found. *Chaetomium* was observed as >1% in the non-culturable air samples and *A. versicolor* was isolated as >30% of the culturable fungi. *Stachybotrys* was not present in indoor air samples.

Mold Hypothesis#14: "Indicator" fungi (i.e., indicators of water intrusion/moisture accumulation of building materials capable of promoting mold growth) are expected to be "not present" in surface dust samples in non-problem buildings.

Null Hypothesis

Fungi commonly associated with water intrusion will be present in surface dust samples collected in non-problem buildings

Test Results

Chaetomium, *Stachybotrys*, and *Trichoderma* were not isolated as greater than 1% of the culturable fungi in vacuum dust samples. *A. versicolor*, *A. flavus* and *A. niger* were not isolated as ≥30% of the culturable fungi in vacuum dust samples. *Penicillium* spp. were not isolated as ≥30% of the cultruable fungi.

Interpretation and Comment

The high prevalence of *Auerobasidium* likely accounts for the overall elevated presence of atypical fungi in dust samples. The other water indicator fungal taxa were rarely isolated in elevated concentrations from the vacuum dust samples.

Null hypothesis is confirmed.

4.4.3 Mold Summary

Cladosporium, was isolated from 100% of the buildings sampled. Airborne *Stachybotrys* spores were never found indoors. However, surface-associated *Stachybotrys* was isolated in 8% of the settled dust (vacuum) samples. The airborne fungal spores in the ten typical office buildings did not vary over the three days nor did they vary by the six indoor locations sampled. Similarly, surface vacuum samples were consistent over the three days of sampling by location and the majority of the buildings demonstrated similar concentrations of spores.

4.5 SOUND

4.5.1 Sound Results

A depiction of the responses of building occupants to questions concerning sound/noise are listed in Appendix P and statistical tables for analyses of questionnaire responses and sound measurements are listed in Appendix Q.

4.5.2 Sound Hypotheses Results

Sound Hypothesis#1: Sound in a work area can annoy or distract occupants.

Null Hypothesis

N/A.

Test Results

To determine the general opinion of acceptable sound/noise, responses of "all of the time" and "most of the time" were summarized as acceptable and responses of "some of the time" and "occasionally" and "never" were summarized as unacceptable. Specific responses by building demonstrate that a majority of occupants rated sounds/noise as acceptable most of the time. Correlation with sound measurements in the buildings were statistically significant ($p<0.05$) for Building 1 (L50_dBA Pearson $p=0.03$), Building 3 (L5_dBA Pearson $p=0.01$ and Spearman $p=0.00$; L50_dBA Pearson and Spearman $p=0.00$; L95 dBA; Spearman and Pearson $p=0.00$), and Building 7 (L95_dBA Spearman $p=0.4$). Moderate significance ($0.05<p<0.075$) was observed for Building 6 (L_5 dBC and L50_dBC Spearman $p=0.06$) and for Building 9 (L95_dBA Pearson $p=0.07$ and Spearman $p=0.06$).

Interpretation and Comments

Building occupants rated the sound/noise in their building as acceptable. Specific responses by building demonstrate that a majority of occupants rated sounds/noise as acceptable most of the time. Larger numbers of respondents may have resulted in the moderate values being listed as statistically significant.

Sound Hypothesis#2: Annoyance or distraction from fluctuations in sound correlates with the midrange of the probability plot of sounds levels over the course of one day using the measurements of L_80 minus L_10 for sound interference level (SIL).

Null Hypothesis

N/A.

Test Results

The majority of respondents reported that the sound in their building did not fluctuate. Specific responses of "never" and "occasionally" and "some of the time" predominated. Correlation with sound measurements in the buildings were only statistically significant ($p<0.05$) for Building 4 (Pearson $p = 0.02$ and Spearman $p = 0.03$).

Interpretation and Comments

Nearly all of the occupants in all of the buildings did not perceive sound as fluctuating during the course of the day. Mid-range of the probability plot of sound levels over the course of one day did not correlate with perceived sound fluctuations except for Building 4. This negative finding may be due to the absence of perceived fluctuation and the low number of participants. Larger numbers of respondents may have resulted in the moderate values being listed as statistically significant.

Sound Hypothesis#3: Sound in the work area that comes from outside the building can annoy or distract occupants.

Null Hypothesis

N/A.

Test Results

This hypothesis was tested using the measurements L_90 minus L_10 for dBA. A series of questions probed this hypothesis. The overall question "Over the past 4 weeks: In general, I'm most comfortable when my work area is…" resulted in a majority of responses liking "neither quiet" nor "loud" with most specific responses stating "somewhat quiet" or "neither quiet" or "loud." When asked if in their work area they could hear sounds from outside of the building such as airplanes, traffic, trains, construction, mechanical equipment, or sirens most respondents replied that they did not hear sounds. When asked how often they heard these sounds, the majority replied "some of the time" or "occasionally" or "never". Statistical correlation was demonstrated with occupant responses and hearing of sounds for Building 3 (Spearman p=0.00), Building 7 (Pearson p=0.02), Building 8 (Pearson p=0.04 and Spearman p = 0.01), and Building 9 (Pearson p=0.00 and Spearman p=0.02). When asked if sound from outside of the building was annoying or distracting the majority of respondents replied that they were not annoyed or distracted and specific answers focused on "never" or "occasionally". However, for Building 2 there was statistical correlation between occupant responses for annoying and outdoor sound measurements (Pearson p=0.02) and moderate significance was observed in this building using Spearman (p=0.07). The majority of respondents replied that sound from outside the building affects their productivity and this occurred all or most of the time. For Building 2 there was statistical correlation between occupant responses concerning productivity and outdoor sounds (Pearson p=0.01). Moderate significance was observed for outdoor sounds and productivity for Building 2 using Spearman (p=0.07). The majority of respondents replied that the period of time between when the sound/noise occurred and they were distracted was brief with the majority of answers on specific time as "a few seconds" and "up to 30 seconds". There were no significant or moderately significant correlations for this question and the sound measurements. The majority of respondents replied that the length of time that they were distracted from sound outside of the building was brief with the majority of answers on specific time as "a few seconds" and "up to 30 seconds". For Building 6 there was moderate significance for the length of annoyance/distraction and sound measurements (Pearson p=0.08).

Interpretation and Comments

Most occupants heard sounds outside the building intermittently or never. Of those occupants who did hear outside sounds, nearly all were neither frequently annoyed nor

was their productivity affected. Most such occupants were annoyed/distracted within 30 seconds, and the sound is annoying/distracting for no more than 30 seconds in 2/3 of affected occupants. The response of hearing sounds outside of the building correlated with the measurement L_90 minus L_10 for dBA for buildings with higher questionnaire participation rates. Larger numbers of respondents may have resulted in other statistically significant results.

Sound Hypothesis#4: Annoyance or distraction from outside sound can be caused by the overall sound level, the intermittent nature (on-off cycle) of the sound, time variations in the sound intensity, or irritating or harsh tones contained in the sound.

Null Hypothesis

N/A.

Test Results

This hypothesis was tested using several measurements. The response of "too loud" was tested using L_99 minus L_50 for dBA. The response of "intermittent/unpredictable" was tested using L_95 minus L_50 for dBA. The response "increases/decreases" was tested using L_80 minus L_50 for dBA. The response "one tone dominates" was not tested by measurements but the response "understandable" was tested using L_90 minus L_50. The majority of responses were either "too loud" or "intermittent/unpredictable", especially by occupants of Building 3. Statistically significant correlations were observed for sound measurements and the response "too loud" for Building 2 (Pearson p=0.04 and Spearman p=0.04) and moderate significance was observed for Building 7 (Spearman p=0.07). Responses of "intermittent/unpredictable" were moderately significant for Building 7 (Pearson p=0.07 and Spearman p=0.07) and "increases/decreases" were moderately significant for Building 9 (Pearson p=0.06). No correlations were observed for "understandable" for any building.

Interpretation and Comments

Sound that is too loud or intermittent/unpredictable accounts for most of the causes of occupant annoyance/distraction from outside sounds. There were not consistent correlations between various sound measurements and characteristics of outside sounds.

Sound Hypothesis#5: Sound in a work area from telephone/speakerphone conversations can annoy or distract building occupants.

Null Hypothesis

N/A.

Test Results

This hypothesis was tested using the measurement of L_80 minus L_50 for sound interference level (SIL) and a series of questions on the occupant perception questionnaire. The responses on hearing of telephone/speakerphone conversations were approximately evenly divided between hearing and not hearing sounds. Specific responses as the frequency of hearing telephone/speakerphone conversations was also mixed. The only statistically significant correlation observed for L_80 minus L_50 for SIL in hearing telephone/speakerphone conversations was Building 9 (Spearman p=0.04). The majority of responses concerning annoyance from telephone/speakerphone conversations were negative and the occurrence of annoyance was mixed. Only

moderately significant correlation for annoyance from telephone/speakerphone conversations and sound measurements was found in Building 6 (Spearman p=0.05). The majority of responses stated that hearing telephone/speakerphone conversations affected their productivity, but "never" or "occasionally" or "some of the time" were the most often cited answers. Correlation between telephone/speakerphone conversations affecting productivity and sound measurements was only observed for Building 6 (Pearson p=0.06 and Spearman p =0.04). "Brief" was most response for the period after which annoyance occurred and responses of "within a few seconds" up to "2 minutes" predominated. "Significant correlation of how quickly the disturbance from telephone/speakerphone conversation occurs and sound measurements was found for Building 7 (Spearman p=0.05). The length of annoyance reported on the questionnaire was mixed and the length varied from a few seconds to 15 minutes. Statistically significant correlation for the length of the disturbance from telephone/speakerphone conversation and sound measurements was found for Building 5 (Spearman p=0.04).

Interpretation and Comments

There is a wide distribution of frequency of hearing sounds from telephone conversations. Annoyance/distraction and adverse impact on productivity is intermittent and the majority of responses concerning annoyance from telephone/speakerphone conversations for the buildings visited was negative. The annoyance/distraction tends to occur soon after the sound is heard, but lasts longer than 30 seconds and this was reflected in the responses of the building occupants.

Sound Hypothesis#6: Annoyance or distraction from sound from telephone/speakerphone conversations in adjacent work areas can be caused by the overall sound level, the intermittent nature of the sound, the intelligibility or content of the sound or the irritating or harsh content in the sound.

Null Hypothesis

N/A.

Test Results

This hypothesis was tested using several measurements. The response of "too loud" was tested using L_95 minus L_50 for SIL. The response of "intermittent/unpredictable" was tested using L_95 minus L_50 for SIL. The response "increases/decreases" was tested using L_80 minus L_50 for SIL. The response "one tone dominates" was not tested by measurements but the response "understandable" was tested using L_90 minus L_50. Responses of "too loud" or "understandable" were most often cited as the cause of annoyance from telephone/speakerphone conversations, but statistically significant correlations were only observed for sound measurements and the response "understandable" for Building 2 (Spearman p=0.03) and Building 5 (Spearman p=0.06).

Interpretation and Comments

Sound that is too loud or understandable accounts for most of the causes of occupant annoyance/distraction from outside sounds. There are not consistent correlations between various sound measurements or calculations and responses to sound from telephone/speakerphone conversations. The L_90 minus L_50 was not significantly correlated with understandable conversation except in Building 2, which had a low questionnaire participation rate, although it was moderately significant in Building 5 which had a higher participation rate.

Sound Hypothesis#7: Sound in a work area from conversations in adjacent work areas can annoy or distract building occupants.

Null Hypothesis

N/A.

Test Results

Most occupants in all buildings frequently heard conversations from adjacent work areas and the frequency of hearing these conversations was mixed. Most occupants were never or only occasionally annoyed/distracted. The majority of respondents reported that their productivity was never or only occasionally affected. The sound most commonly annoys or distracts occupants within 30 seconds and the majority responded that it was a brief period after hearing the conversations that the annoyance/distraction occurs. Ranges from "within a few seconds" to "up to two minutes" the most often cited times. The duration of time that the annoyance/distraction continued was divided among the respondents as there was a wide distribution of the duration of annoyance/distraction. Statistically significant correlation between the L_80 minus L_50 for SIL sound measurement and occupant perception questionnaire responses were observed for hearing of conversations Building 1 (Spearman p=0.02), Building 3 (Pearson p=0.00), and Building 9 (Pearson and Spearman p=0.00). No correlations were observed in any buildings for the conversations being annoying, having an affect on productivity, or for the time within the annoyance occurs. Statistically significant correlations were found for the duration of the time of annoyance/distraction and the sound measurement for Building 4 (Pearson p=0.04 and Spearman p=0.03) and Building 6 (Spearman p=0.03). Moderate correlation was also observed for Building 6 using Pearson (p=0.06).

Interpretation and Comments

Most respondents reported frequently hearing conversations from adjacent work areas. However, most were never or infrequently annoyed/distracted and their productivity was never or infrequently affected. The sound most commonly annoyed or distracted within a short time, but there was a wide distribution of the duration of annoyance/distraction. The measurement L_80 minus L_50 for SIL did not consistently correlate for any of the questions concerning sound from conversations in adjacent work areas.

Sound Hypothesis#8: Annoyance or distraction from sound from conversations in adjacent work areas can be caused by the overall sound level, the intermittent nature of the sound, the intelligibility or content of the sound or the irritating or harsh content in the sound.

Null Hypothesis

N/A.

Test Results

This hypothesis was tested using several measurements. The response of "too loud" was tested using L_99 minus L_50 for SIL. The response of "intermittent/unpredictable" was tested using L_95 minus L_50 for SIL. The response "increases/decreases" was tested using L_80 minus L_50 for SIL. The response "one tone dominates" was not tested by measurements but the response "understandable" was tested using L_90 minus L_50. Respondents to the occupant perception questionnaire answered that most of the annoyance/distraction from conversations in the work area was associated with the sound being too loud or being understandable. However, there was no statistical correlation

between the sound measurements and the occupant responses except for Building 2 (Spearman p=0.03) which had a low response rate.

Interpretation and Comments

Sound that is too loud or understandable accounts for most of the causes of occupant annoyance/distraction. There were no consistent correlations between various sound measurements or calculations and occupant responses to sound from overflow conversations from adjacent work areas. The L_99 minus L_50 did not correlate with understandable sound or conversation except in Building 2 which had a very low participation rate.

Sound Hypothesis#9: Sound in a work area from piped-in music or background masking system can annoy or distract building occupants.

Null Hypothesis

N/A.

Test Results

This hypothesis was tested using the sound measurements L_50 minus L_10 for dBA with the assumption that the values will inversely correlate with background noises. The majority of the respondents never hear music or masking sounds in their work area. Most respondents were never or infrequently annoyed/ distracted by it, although no responses were recorded for Building 2 and Building 5 for this question. The majority responded that music or masking did not affect productivity, although no responses were recorded for this question in Building 2 and Building 5. After hearing the sound it is a brief period until it is distracting and the length of the distraction is long. No statistical correlation was observed for hearing of piped music or masking, or the period of this between hearing the sound and being annoyed and sound measurements in any of the 10 buildings. However, significant inverse correlation with L_50 minus L_10 for dBA was observed for annoyance in Building 9 (Pearson p=0.02 and Spearman p=0.075) and for the duration of the annoyance for Building 8 (Spearman p=0.075).

Interpretation and Comments

The majority of respondents never hear piped in music or masking sounds. Of those that did, most were only infrequently annoyed/distracted. The measurement L_50 - L_10 for dBA does not consistently inversely correlate with background noises from piped-in music or masking sounds.

Sound Hypothesis#10: Annoyance or distraction from sound from piped in music or masking sounds can be caused by the overall sound level, the intermittent nature of the sound, the intelligibility or content of the sound or the irritating or harsh content in the sound.

Null Hypothesis

N/A.

Test Results

This hypothesis was tested using L_80 minus L_10 for dBA for “too loud” and L_80 minus L_50 for dBA for “intermittent/unpredictable” and “increases/decreases.” The response “one tone dominates” was not tested by measurements, but the response “understandable” was tested using L_80 - L_50 for dBA. Of the small number of

respondents who heard piped-in music or masking sounds, there were several reasons for distraction, with no one predominating. The only statistically significant correlation was observed in Building 10 (Pearson p=0.02 and Spearman p=0.01) and "too loud."

Interpretation and Comments

Of the small number of respondents who hear piped-in music or masking sounds, there are several sources of distraction, with no one predominating. None of the perception questionnaire resposnses correlated with the various calculated measurements, except for Building 10.

Sound Hypothesis#11: Sound in a work area from nearby office equipment (e.g., copy machines, typewriters) annoys or distracts building occupant.

Null Hypothesis

N/A.

Test Results

This hypothesis was tested using L_90 minus L_50 for noise criteria (NC). The majority or respondents did not hear sounds of office equipment, with 78% selecting "never" or "occasionally". Of those who heard office equipment sounds, nearly all (95%) were infrequently or never annoyed/distracted and 97% never or infrequently had productivity affected. The sound most commonly annoys or distracts quickly within 30 seconds, and 59% reported that the annoyance/distraction lasts a brief period, less than 2 minutes. Statistically significant correlations were observed for hearing equipment sounds) for Building 1 (Spearman p=0.04) and 10 (Pearson and Spearman p=0.00). Moderately significant correlation was also found for Building 1 (Pearson p=0.05). No correlations were found for the other variables of annoyance, productivity affected, period of time from hearing equipment sound to annoyance/distraction or the length of the annoyance/distraction.

Interpretation and Comments

Most respondents never or only occasionally heard sounds of office equipment. Of those who heard those sounds, nearly all were infrequently or never annoyed/distracted and never or infrequently had productivity affected. It was a brief period to distraction and it lasted a short time.

Sound Hypothesis#12: Annoyance or distraction from the sound of office equipment (e.g., copy machines, typewriters) can be caused by the overall sound level, the intermittent nature of the sound, the intelligibility or content of the sound or the irritating or harsh content in the sound.

Null Hypothesis

N/A.

Test Results

This hypothesis was tested using L_90 minus L_10 for NC for "too loud" and L_90 minus L_50 for NC for "intermittent/unpredictable" and L_80 minus L_50 for NC for "increases/decreases." The response "one tone dominates" was not tested by measurements, but the response "understandable" was tested using L_80 minus L_50 for NC. Sounds from nearby office equipment that were "too loud" or "intermittent /unpredictable" represented the majority of responses for annoyance/distraction.

Statistically significant correlation was observed for the sound measurement and the response "too loud" for Building 1 (Pearson p=0.047 and Spearman p=0.03) and For Building 6 (Spearman p=0.02). Moderate correlation was also observed for Building 6 (Pearson p=0.07). Statistically significant correlation was observed for the sound measurement and the response "intermittent/unpredictable" for Building 2 (Pearson p=0.00 and Spearman p=0.03) and For Building 6 (Pearson and Spearman p=0.03).

Interpretation and Comments

Sounds from nearby office equipment that are too loud or are intermittent/unpredictable represent most of the reasons of annoyance/distraction. No measured or calculated sound values consistently correlated with perception questionnaire responses regarding sound from nearby office equipment.

Sound Hypothesis#13: Sound in a work area from mechanical equipment within a building annoys or distracts occupants.

Null Hypothesis

N/A.

Test Results

This hypothesis was tested using sound measurements L_80 minus L_10 for RC. The majority of respondents did not report hearing the sound of mechanical equipment in the building and specifically replied "never" when asked the frequency of hearing mechanical sounds. The majority of respondents was not annoyed/distracted by mechanical sounds and replied "never" or only "occasionally". The majority did not report affect on their productivity and specifically responded "never" or "infrequently". The period of time before a mechanical sound becomes distracting was brief, generally within 30 seconds, and the period of distraction generally was also brief and within 30 seconds. Statistically significant correlation was observed for sound measurements L_80 minus L_10 for RC and hearing of mechanical sounds for Building 7 (Pearson p=0.01 and Spearman p=0.02) and Building 9 (Pearson p=0.01 and Spearman p=0.00). Moderate correlation was observed for Building 6 (Pearson p=0.05). Significant correlation was observed for the sound measurements and the duration that the distraction occurred for Building 10 (Pearson p=0.05). The majority of respondents answered that the mechanical sounds came from the ceiling, but "can't tell" was also noted. The sound of the mechanical equipment was predominately described as a "hiss/whistle" or a "rumble'.

Interpretation and Comments

Most occupants in all buildings never or only occasionally heard sounds from mechanical equipment. Of those who did, nearly all were infrequently or never annoyed/distracted and never or infrequently had their productivity affected. The sound most commonly annoyed or distracted within 30 seconds, but there was a wide distribution of its duration. None of these questions correlated consistently with L_80 minus L_10 for RC.

Sound Hypothesis#14: Annoyance or distraction from the sound of mechanical equipment within the building can be caused by the overall sound level, fluctuations in the sound intensity or harsh tones contained in the sound.

Null Hypothesis

N/A.

Test Results

This hypothesis was tested using the sound measurements L_80 minus L_10 for NC for "too loud" and L_80 - L_50 for NC for intermittent/unpredictable. L_80 minus L_50 for NC for "increases/decreases." The response "one tone dominates" was not tested by measurements, but the response "understandable" was tested using L_80 minus L_50 for NC. Sounds from mechanical equipment that were too loud or intermittent/unpredictable represented most of the reasons for annoyance/distraction. Statistically significant correlations were observed for "too loud" and the sound measurements for Building 4 (Pearson p=0.01 and Spearman p=0.02) and Building 6 (Pearson and Spearman p=0.02). Statistically significant correlation was observed for Building 6 (Spearman p=0.01) and Building 7 (Pearson p=0.03) for "increases /decreases." No correlation was observed for "understandable."

Interpretation and Comments

Sounds from mechanical equipment that were "too loud" or "intermittent/unpredictable" were the most distracting, but most responses were not annoyed/distracted. No measured or calculated sound values consistently correlated with occupant perception questionnaire responses regarding sound from mechanical equipment.

Sound Hypothesis#15: Sound in a work area from the air conditioning system (air supply or air return) within a building annoys or distracts occupants.

Null Hypothesis

N/A.

Test Results

This hypothesis was tested using L_80 minus L_50 for RC, RC® [rumble]. Most (70%) respondents reported never or occasionally hearing sounds from air supply or return diffusers, but 17% heard it constantly. Of those who did hear these sounds, most (76%) were infrequently or never annoyed/distracted. The majority (88%) of respondents' productivity was not affected and reported "never" or "infrequently" on specific responses. The time period from hearing the sounds and being annoyed/distracted is generally brief and the sound most commonly annoys or distracts within 30 seconds. The duration of the annoyance/distraction is brief and is usually <30 seconds. Statistically significant correlation was observed with L_80 minus L_50 for RC; RC® [rumble] and hearing the sounds for Building 2 (Pearson p=0.03). Significant correlation was observed for being annoyed for Building 6 (Pearson p=0.02). No correlation was found for affecting productivity or for the time period within the sound was annoying. However, statistically significant correlation was observed for Building 7 (Spearman p=0.04) and Building 10 (Pearson and Spearman 0.00) for the length of the disturbance.

Interpretation and Comments

Most of the occupants never or only occasionally heard sounds from air supply or return diffusers. Of those who did hear these sounds, most were infrequently or never annoyed/distracted and their productivity was never or infrequently affected. The sound most commonly annoyed or distracted within 30 seconds, and the duration of the annoyance/distraction was usually less than 30 seconds. None of the occupant perception questions consistently correlated with L_80 minus L_50 for RC.

Sound Hypothesis#16: Annoyance or distraction from sound from ceiling or floor air-supply diffusers can be caused by the overall sound level, the intermittent nature of the sound, fluctuations in the sound intensity or the irritating or harsh tones contained in the sound.

Null Hypothesis

N/A.

Test Results

This hypothesis was testing using the sound measurement L_90 minus L_10 for RC for "too loud." L_90 minus L_50 for RC was used for the response "intermittent/unpredictable" and L_80 - L_50 for RC was used for the response "increases/decreases." The response "one tone dominates" was not tested by measurements, but the response "understandable" was tested using L_80 minus L_50 for NC. The majority of respondents selected "too loud" (46%), intermittent/unpredictable (20%), or one tone dominants (25%) when asked the cause of the annoyance/disturbance from sounds from ceiling or air supply diffusers. Statistically significant correlation was observed for sound measurements and "too loud" for Building 4 (Pearson p=0.03 and Spearman p=0.04) and Building 6 (Pearson 0.03 and Spearman 0.048). Moderate correlation was observed for sound measurements and "intermittent/unpredictable" for Building 9 (Spearman p=0.053). Statistically significant correlation was observed for "increases/decreases" for Building 7 using Pearson (p=0.02) and moderate correlation was found using Spearman (p=0.06). Nearby walls was the location most often cited as the location of the sound from air diffusers/supply registers and a variety of sounds were reported.

Interpretation and Comments

Too loud or intermittent/unpredictable sounds from ceiling or air supply diffusers represented most of the reasons of annoyance/distraction. No measured or calculated sound values consistently correlated with occupant perception questions regarding sound from ceiling or air supply diffusers.

Sound Hypothesis#17: Conditions that allow building occupants to clearly hear other people talking, having telephone and/or speakerphone conversations can cause workers to believe that they cannot have a private conversation in their work area.

Null Hypothesis

N/A.

Test Results

This hypothesis was testing using sound measurements L_50 for SIL. The respondents varied in their responses to privacy to have a private conversation. Respondents also were asked about telephone privacy and responses were mixed. There was little

correlation for the sound measurement and these questions. The only correlation was observed in Building 8 were moderate significance was observed for telephone privacy (Pearson p=0.08).

Interpretation and Comments

There is wide variability in the proportion of respondents and the extent of sound privacy acceptability, including speech privacy for person-to-person and telephone conversations. Responses to the perception questionnaire consistently correlated with L_50 for SIL only in one building which had the highest participation rate.

Sound Hypothesis#18: If building occupants believe they cannot have a private conversation in their work area, they will move to a more private area for confidential conversations.

Null Hypothesis

N/A.

Test Results

This hypothesis includes conversations on the telephone and was tested using sound measurements L_50 for SIL. Respondents were divided as to moving to another location to obtain privacy. The only correlations observed for sound measurements and responses to these questions concerning privacy were observed in Building 8. Statistically significant correlations for this building were observed for leaving to have a conversation (Pearson p=0.04). Moderate significance was observed using Spearman (p =0.051). Responses were varied when asked if they moved to another location to obtain telephone privacy. Statistically significant correlation was observed for leaving the area to have a telephone conversation (Pearson p= 0.02).

Interpretation and Comments

There is wide variability in the proportion of respondents and the extent of sound privacy acceptability, including speech privacy for person-to-person and telephone conversations. The only correlation between perception responses and L_50 for SIL was observed in one building which has the highest participation rate.

Sound Hypothesis#19: If building occupants believe they cannot have a private conversation in their work area, they will postpone confidential conversations to a time when people are not present in adjacent areas.

Null Hypothesis

N/A.

Test Results

This hypothesis included telephone conversations and was tested using sound measurements L_50 for SIL. Many of the respondents postpone conversations until a later time to gain privacy. The only correlations observed for sound measurements and responses to these questions concerning privacy were observed in Building 8. Statistically significant correlation was observed for postponing a conversation until later (Pearson p=0.02). Postponing telephone conversations to obtain privacy was a common response. Statistically significant correlation was observed for postponing a telephone call until later (Pearson p=0.00). The questionnaire also asked if they closed a door to gain privacy. Many occupants responded that they closed a door to obtain privacy.

Interpretation and Comments

There is wide variability in the proportion of respondents and extent of sound privacy acceptability, including speech privacy for person-to-person and telephone conversations. Occupant perception questionnaire responses concerning privacy only consistently correlated with L_50 for SIL in one building which has the highest participation rate for the questionnaire.

4.5.3 Sound Summary

Results of the sound portion of the occupant questionnaire by building and field measured sound level data, by building and by minor location ID number are in **Appendix Q**. For the correlation, an assumption was made that the data for both microphones and all three days could be combined to form a single measure per zone. Correlation of the perception data and measured sound level data was performed for each building and question affinity group combination. An affinity group normally has five related questions dealing with that type of sound. The questions ask if the sound is heard, does it annoy or distract, does it affect productivity, within how long does it affect productivity, and for how long does it affect productivity.

4.6 LIGHTING

4.6.1 Lighting System Results

A brief description of the ten buildings' lighting systems is found in Table R1 (**Appendix R**). Most of the buildings monitored have cubicle setups, while Building 9, 10 and part of Building 8 have open office setups. The cubicle partitions are about 1.66 m (5.4 ft) high, while the open office partitions are only 1.06 to 1.26 m (3.5 to 4.2 ft) high.

The ambient lighting systems of six of the buildings are direct recessed fluorescent with parabolic louvers, and those of the other four are direct/indirect fluorescent, pended mounted. All the building ambient lighting systems have four feet 32 W T8 light sources, but with different correlated color temperatures (CCT) and color rendering index (CRI). The CCT and CRI numbers provided in the table were measured by a Lightspex spectrometer, and thus are different from the nominal values marked on the lamps. The CCTs vary from 3100 K to 3840 K, and CRIs were from 75 to 86.

Except for Building 10 and part of open office area in Building 8, all the other buildings have task lights, most of which are furniture-integrated units, and only one building uses desk movable units. The light sources used in the task lights are T8, T12 and compact florescent lamps (CFL). The CCT ranges from 2718 to 3913 K and CRI ranges from 63 to 85. Note that Buildings 6 and 8 have relatively low CRIs, 63 and 67, respectively, which have very poor color rendering capability.

Buildings 6, 8 and 9 are Leadership in Energy and Environmental Design (LEED) certified buildings with ratings of gold, silver and platinum respectively. Although all the buildings have windows, three LEED buildings have more windows, and provide more daylight and window views for their occupants than the other buildings. This is because the U.S. Green Building Council gives LEED credits for buildings that provide daylight to 75% of spaces and views for 90% of space. Except Building 9, all the others have blinds as daylight controls. Building 9 has overhang, but no blinds, and it uses neutral color low-transmittance windows with transmittance from 18% to 37% at different locations.

The main lighting control systems in the buildings are timing devices and local override light switches. Most buildings have occupancy sensors in some areas, such as meeting rooms and copy rooms. Buildings

1, 2 and 3 have occupancy sensors for task lighting. Building 6 has dimming ballasts and photosensors for ambient lighting systems. According to its building facility manager, however, dimming ballast and photosensors are not functional because of lighting design problems.

4.6.2 Lighting Measurement Results

Measurement results including illuminance, luminance, color property and LPD, of ten office buildings are summarized in Appendix S. The mean and standard deviation values of measurements for each building are listed, providing baseline lighting measurement data for typical office buildings. Figure S1 provides illuminance-related measurements of ten buildings. For each building, its mean and standard deviation over 18 measured workstations are shown in the figure. Figure S1 (a) plots illuminances at work surface, which were computed by averaging four measurements at far left, far right, near left and near right of primary surfaces. The overall illuminance at work surfaces of ten buildings was 657 Lux with the standard deviation of 243 Lux. The design guide recommends 300 to 500 Lux for office lighting, depending on the characteristics of visual tasks. The measured illuminance is higher than the high end of this design range. The LEED certified buildings (Buildings 6, 8, 9 and 10), which all use direct/indirect lighting systems, had lower average illuminance at the work surface than the other buildings, which use direct lighting systems. Figure S1 (b) illustrates the uniformity of illuminance at the work surface, which was computed by averaging the ratio of the maximum illuminance to the average illuminance at work surface and the ratio of the maximum illuminance to the average illuminance at work surface. The overall uniformity was 1.91 with the standard deviation of 1.15. A uniformity of less than 3.0 is generally considered uniform. The IESNA lighting handbook lists the uniformity of light distribution on task plane as one of the important design criteria. Figure S1 (b) shows that most buildings had uniform lighting distribution at the work surface, except Building 3 that had greater uniformity and larger variations. The three buildings with direct/indirect lighting systems (Buildings 6, 8, 9 and 10) had more uniform light distribution and lower variations.

Figures S1 (c) and (e) plot illuminances at the center of screens, at source documents and keyboards of VDTs. The illuminance at the center of screens is close to the vertical illuminance in offices. The vertical illuminance is considered a very important design criterion in offices, and the recommendation value is 500 Lux. The average measured illuminance at the screens was 339 Lux, which is lower than the recommendation value. The average illuminance at VDT source documents and keyboards were close, 574 Lux and 525 Lux, respectively. Figures S1 (f) shows illuminances at the floor for all the buildings. The average was 350 Lux with the standard deviation of 143 Lux. Figure S2 provides luminance-related measurements. Figures S2 a-c display luminances at ceilings between luminaires, at brightest ceilings and at brightest light sources in field of view. The luminances at ceilings in direct/indirect lighting systems are much higher than those in direct systems, due to the influence of upbeat light in the direct/indirect systems. The average luminances between luminaires were 98 and 36 cd/m^2 for buildings with direct/indirect and direct systems, respectively. The results for luminances at brightest ceilings were 471 and 55 cd/m^2 for two systems, respectively. In addition, the variations in direct/indirect systems were much higher than those in direct systems. The luminances at brightest light sources were 2089 and 4839 cd/m^2 respectively, for two different lighting systems. Compared to direct/indirect systems, direct systems obviously have much brighter light sources and darker ceilings.

Figure S2 (d) plots luminances at floor levels. The luminance greatly depends on floor colors. Dark colors are normally used on floors. The average floor luminance measured in this study was 10 cd/m^2. Figures S2 e-f show luminances at partitions or walls, and at the darkest partitions or walls in the field of view. These two results were significantly affected by the colors of partitions and influence of daylight. The average luminance at partitions was 49 cd/m^2 with the standard deviation of 45 cd/m^2. The luminance at darkest partitions or walls in field of view was 16 cd/m^2 with the same magnitude of standard deviation. Daylight

had great influence on a large number of workstations in Building 9, which caused large variations in partition luminances.

Figure S3 a-b illustrate luminances at nearby buildings and at brightest sky from windows, respectively. The results greatly depended on the weather, window orientation and measurement time. These data provide an indication of luminances and variations from windows in a typical office building. Figure S4 a-b show CRIs and CCTs of the lighting measured at the work surface for all the buildings. The average CCT was 3387 K, which is considered a slightly warm color. The average CRI was 81, which is considered to be fair color rendering properties. IESNA recommends using lamps with CRI of 70 or greater in offices, or 85 CRI or above if color critical tasks are being performed. According to these observations, no color critical tasks were performed in any office buildings. Therefore, color rendering capabilities of the lighting in these offices should be appropriate.

The ANSI/ASHARE/IESNA standard recommends 10.76 W/m^2 (1.0 W/ft^2) for office spaces. The lighting power density for ten office buildings overall is 12.71 W/m^2 (1.18 W/ft^2), 18% over the recommended value. The six non-LEED buildings, using direct systems, have 14.27 W/m^2 (1.33 W/ft^2), and four LEED buildings, using direct/indirect systems, have 10.37 W/m^2 (0.96 W/ft^2). The ANSI/ASHARE/IESNA standard recommends 10.76 W/m^2 (1.0 W/ft^2) for office spaces. Building 9 had very low LPD, only 6.89 W/m^2 (0.64 W/ft^2), because this building uses a great deal of daylight.

Multivariate analysis of variance (MANOVA) was used to analyze whether different buildings had statistically different lighting measurements. The building was the independent variable with ten levels (Buildings 1 to 10). The six key measurements, including illuminance at work surface, luminance at walls or partitions, luminance at floor, luminance at ceilings between luminaires, luminance at brightest ceilings, luminance at brightest light sources, were used as dependent variables. Multivariate tests show that the buildings had significantly different lighting measurements [$F(54, 1020) = 9.411$, $p < 0.001$]. Univariate testing for the six dependent variables showed that all these dependent variables are significantly different [all $p < 0.001$].

The same MANOVA analysis was performed for buildings with direct lighting systems (Buildings 1-5, and 7). The results show that the buildings had significantly different lighting measurements [$F(30, 505) = 3.713$, $p < 0.001$], although they all use direct systems. Univariate testing for the six dependent variables showed that all these dependent variables are significantly different [all $p < 0.05$].

The analysis was also performed for buildings with direct/indirect lighting systems (Buildings 6, 8, 9 and 10). The results showed that the buildings had significantly different lighting measurements [$F(18, 195) = 12.7606$, $p < 0.001$], although they all use indirect systems. Univariate testing for the six dependent variables show that five of all these dependent variables are significantly different [all $p < 0.05$], except the luminance at brightest are not significantly different for buildings [$F(3, 68) = 1.782$, $p = 0.159$].

In summary, the above analyses show that there are significant differences in lighting measurements for different buildings.

For each building, a total of 18 workstations were measured in three days, with six measurements in each day. The MANOVA statistical method was used to analyze whether different days had different lighting results. The day is taken as the independent variable with three levels (Tuesday, Wednesday and Thursday). The six measurements, same as in the above analysis, are used as dependent variables. Separate tests were run for different buildings. Multivariate tests show that the day is significant only to Building 3, [$F(12, 22) = 6$, $p = 0.02$]. All the other eight tests show that the day is not significant, with p values of 0.835, 0.367, 0.661, 0.807, 0.991, 0.756, 0.301, 0.291 and 0.852 for Buildings 1, 2 and 4 to 10, respectively. The results of a univariate test for Building 3 shows that two of the six measures, illuminance at work surface [$F(2, 157737) = 6$, $p = 0.12$] and illuminance at partitions or walls [$F(2, 150.2) = 3.76$, $p = 0.047$] are significantly different.

From the above statistical analyses, it was determined that the lighting measurements were not significantly different for different days for most of buildings, with only one exception, Building 3.

A question in the perception questionnaire asked about the respondents' attitudes toward brightness in office work areas ("I am most comfortable when the lighting in my work area is: very bright, somewhat or slightly bright, neither bright nor dim, somewhat or slight dim, or very dim or dark"). Most lighting experts believe that people should be most comfortable when the lighting in the work area is neither bright nor dim. Only 24% respondents, however, chose this answer. Most respondents (69%) liked very bright and somewhat or slightly bright lighting in their work area. Seven percent respondents liked somewhat dim lighting. This result is very important, allowing correlation of brightness perception with psychological comfort.

Figure S5 a-b provide the results of two questions regarding brightness on work surfaces and computer screen. As can be seen, most respondents thought that the lighting on their desk and computer screens was somewhat bright or neither bright nor dim. These results correspond with the illuminance measurements, which were 657 Lux on the work surface and 339 Lux on the computer screens.

Figure S6 shows the repondents' answers on the uniformity of light distribution across work surfaces. A majority of respondents felt that lighting was uniform. This result also corresponds with the measurement, which was 1.9 for the ten buildings overall.

Figure S7 shows that about a third of office occupants (35%) experienced direct glare sometime during the day, and the most noticeable source was direct sunlight or daylight in general. Ceilings can also be important glare sources. Figure S8 provides the result of reflected glare on computer screens. It shows that some office occupants (28%) experienced reflected glare sometime during the day, and the most noticeable glare source was sunlight or daylight.

There are two questions on the perception questionnaire related to color property of the lighting: whether the color of people's faces and objects appear natural, and whether the lighting is visually cool or warm. These two questions were designed according to two important color properties of lighting, color rendering and color temperature. Results show that 70% of respondents agreed the color appeared natural, only 5% did not agree, and the other 25% were neutral or did not know. The results of the second question show that most respondents (79%) were neutral or did not know how to answer the question.

During this study, it was found that many people (none of whom were lighting experts) had a difficult time in answering these two questions. People generally do not pay much attention to color rendering and the color tone of lighting, due to lack of lighting knowledge. Although they may observe some differences in the colors of objects, they seldom correlate this with the lighting. The answers given for these two questions show a high percentage of neutral opinions or did not know, which emphasizes this point.

Among 394 respondents, 64% of them were in the buildings with windows facing the outdoors. Only these respondents were allowed to answer questions regarding daylight. The results of the survey show that a majority of these people (91%) who answered questions preferred natural light, and only less than 2% somewhat disliked natural light.

Approximately 19% of the respondents thought the amount of lighting entering their work area was very or somewhat excessive. 71% thought it was neither excessive nor insufficient, and 10% thought it was somewhat or very insufficient.

When the amount of natural sunlight or daylight that enters the office or work area was excessive or insufficient, 66% of the respondents never or occasionally adjusted windows drapes or blinds. 7% of the respondents adjusted some of the time, and 26% adjusted most of time or all of the time.

In the questionnaire occupants were queried about flickering, buzzing sounds, irregular and distracting lighting patterns, and shadows. The survey results show flickering and buzzing sounds are not a big

problem as less than 2% of respondents experienced flickering or buzzing sounds most of the time or all the time. This may be because electronic ballasts which generally do not produce flickering or noise were used in all of the buildings surveyed. Irregular lighting patterns were also not a reason for complaints, because less than 2% of respondents noticed them. Shadows were also not a big problem: over 83% of respondents did not observe much shadow, and only 10% reported some shadows in their work area.

There are two very similar questions regarding respondents' satisfaction towards the overall lighting environment. One is, "in the past 4 weeks, I would rate my satisfaction with the lighting in my work area," and the other is, "over the past 4 weeks, I have been satisfied with the lighting in my office." These two questions are placed at the beginning and near the end of the group of lighting questions. This repetition was designed intentionally because respondents' satisfaction towards lighting was very important information, and reliable answers could be obtained by asking them repetitively. In both these questions, a time frame of the past four weeks was added, because the building lighting may change over time, and this time frame helps clarify the questions.

The answers to these two questions are shown as **Figure S9**. The results of two questions were very close, which suggested that respondents take the questions seriously and they had consistent opinions about their lighting satisfaction. A majority of respondents (72%) were satisfied with their lighting, with 36% (averaging the results of two questions) were very satisfied and the same percentage of respondents were somewhat satisfied. About 14% of the respondents had neutral opinions, and 12% were somewhat dissatisfied, while 2% were very dissatisfied.

In the questionnaire, there are four questions related to productivity. The results are shown in **Figure S10**. As to the first question, "the quality of lighting in my work area is important to my ability to be productive in my job," about 90% of respondents agreed, 9% stayed neutral and only 0.8% somewhat disagreed. This result suggests that occupants believe that lighting is an important indoor environmental factor, which affects the occupants' productivity.

The second question is regarding the lighting factor that most adversely affects productivity. About 23% of respondents chose that the lighting is too bright or too dim. Another 19% of respondents chose too much glare. Very few respondents chose other factors, including light flickering, lighting patterns and distorted colors. About 42% of respondents did not answer this question at all.

As to the question, "when there is too much glare on my desk surface or workstation, and/or on my computer screen, my productivity is adversely affected," 70% of respondents believed that their productivity never or only occasionally was affected by glare, but 20% thought they were affected some of the time and 10% were affected most of the time or all the time.

The last productivity related question is, "when the lighting in my work area, on my desk surface or workstation, and/or on my computer screen is deficient or unacceptable during my work day, my productivity is adversely affected." The results were similar to the above question regarding glare. Also, most respondents (68%) did not think their productivity was affected by deficient or unacceptable lighting, but about a third of respondents (32%) thought they were affected some of the time, most of time or all the time.

In summary, from the results of these four productivity related questions, it was found that: 1) most respondents believe that the quality of lighting is important to their productivity; 2) lighting levels and glare are the most important lighting factors that affect productivity; and 3) approximately a third of respondents think inappropriate lighting levels and too much glare affect their productivity.

4.6.3 Lighting Hypotheses Results

Lighting Hypothesis#1: Most people will be comfortable when the lighting in their work areas is neither too bright nor too dim.

Test Results

The results of the occupant perception questionnaire show that only 24% respondents chose "neither too bright nor too dim" and most respondents (71%) chose "very bright" and "somewhat or slightly bright" lighting in their work area.

Lighting Hypothesis#2: The lighting over 700 Lux on the work surface will be considered as "very bright" or "somewhat bright" and lower than 300 Lux may be considered as "very dim or dark" or "somewhat dim or dark."

Test Results

The mean illuminances at work surface of three buildings (Building 3, 4 and 7) were over 700 Lux and the median values of occupant perception questionnaire results are "somewhat bright." In comparison, the median illuminances at work surface of two buildings (Building 8 and 9) were lower, 547 and 542 Lux respectively, and the median responses of the perception questionnaire were "neither bright nor dim." In the second part of the hypothesis there are not enough data, because no building had a mean illuminance lower than 300 Lux.

Lighting Hypothesis#3: Lower than 50 Lux of the lighting at computer screens will be considered as "very dim or dark" or somewhat dim or dark".

Test Results

All the measurements in this questionnaire are much greater than 50 Lux at the computer screens, with the average of 327 Lux. Most respondents evaluated the lighting at their commuter screens as "neither bright nor dim" and some evaluated it as "somewhat bright."

Lighting Hypothesis#4: The uniformity of illuminance less than 3 at work surfaces will be considered as uniform.

Test Results

Eight buildings had the uniformities <3 and Building 3 had the uniformity a little higher (3.5). All the buildings had median values of perception questionnaire results of "somewhat uniform."

Lighting Hypothesis#5: When there is too much glare on desk surfaces or workstations, and/or on my computer screen, most occupants' productivity will be adversely affected.

Test Results

The occupant perception questionnaire results show that 70% of respondents believed that their productivity never or only occasionally was affected by glare and only 30% believed that they were affected from some of the time to most of the time and all the time.

Lighting Hypothesis#6: Most people prefer to have natural light from outdoors come into their office or work area.

Test Results

The results of the questionnaire show that a majority of respondents (91%) who answered questions preferred natural light, and only less than 2% somewhat disliked natural light.

Lighting Hypothesis#7: If the CRI of lighting is 75 or greater, the color of people's faces and objects in work area will appear natural.

Test Results

The CRIs of all the buildings were all over 75 and with the average of 81. The median answers of the perception questionnaire results were that respondents somewhat agreed that people's faces and objects in work area appear natural.

Lighting Hypothesis#8: The CCT of the lighting lower than 3000 K will be evaluated as visually warm and higher than 5000 will be evaluated as visually cool.

Test Results

All the buildings recorded CCTs between 3000 to 5000 K and most respondents had neutral opinions or did not know how to answer this question.

5. CONCLUSIONS

5.1 BUILDING CHARACTERISTICS

Access to office buildings was problematic. Therefore, the geographic and climate diversity of the monitored buildings was compressed. Details of the building characteristics are listed in Appendix T. The true value of the data in this study will increase as additional building measurements are added to the database.

Placement of monitoring instrumentation required space in work areas without disruption of the work activities of the space. Every effort was made to be the least disruptive as possible as still gather reliable data representative of the building. Figure 12 depicts the standard set up of the static instrumentation (IEQ and sound). Lighting and mold measurements were made with additional instrumentation by a member of the research time visiting the area.

Figure 12. Standard setup of the static IEQ and sound instrumentation.

5.2 THERMAL COMFORT/ INDOOR ENVIRONMENTAL QUALITY

Temperature was perceived as acceptable by a majority of respondents in all buildings (Figures 1-10). There is limited inter-zone variability in the perception of thermal comfort. Temperature fluctuation between AM and PM was not problematic in the population of buildings studied. In most buildings where occupants can adjust the temperature themselves via thermostat, <10% did so in response to temperature too cool, whereas the proportion approached 10% in response to too warm. The prevalence of adverse work productivity perception was relatively low compared with overall perception of thermal acceptability. Vertical temperature gradients were within the acceptable level in all buildings. Thermal acceptability was not associated with perception of thermal discomfort in a particular body part. Most

occupants report perceived humidity as acceptable most or all of the time in all buildings. Fluctuations in humidity were uncommon. Most occupants in all the buildings did not report conditions to be too dry or too hot; of those who did, most do not make adjustments. Most buildings had an average draft rate that was less than 15%. A majority of respondents found draft acceptable. Although unacceptability of the draft parameter was higher than postulated, most occupants did not respond to the problem by making adjustments, nor did most perceive it as having an adverse impact on work productivity. Most respondents found the air in the work environment acceptably fresh and infrequently stuffy. Among those respondents who perceivde the air as being stuffy at least some portion of the work day, nearly all did not make adjustments to their workplace to address the problem. Air stuffiness did not appear to significantly impact work productivity. Nearly all occupants of this set of non-problem buildings did not report frequent odors. Among those who did, food odors were consistently the most frequent type of odor.

5.3 AIRBORNE AND SURFACE-ASSOCIATED MOLD

The most prevalent airborne fungal spore worldwide, *Cladosporium,* was isolated from 100% of the buildings sampled. Airborne *Stachybotrys* spores were never found indoors. However, surface-associated *Stachybotrys* was isolated in 8% of the settled dust (vacuum) samples. The airborne fungal spores in the 10 typical office buildings did not vary over the three days nor did they vary by the six indoor locations sampled demonstrating that for non-water damaged buildings the airborne fungal spore populations can be characterized with a single day of sampling in a limited number of locations. Similarly, surface vacuum samples were consistent over the three days of sampling by location and the majority of the buildings demonstrated similar concentrations of spores. However, in four of the 10 buildings there were wide ranging concentrations indicating variability in the presence of settled spores in the sampled locations. A larger data set of vacuum samples is needed to address variability by day and by location.

5.4 SOUND

The literature review indicated that the physical sound environment does affect occupant's perception of the indoor environment, but that other factors not directly related to or affecting sound may influence that perception. The search for correlation of perception and actual environment involves analysis of the data from the questionnaire and the field measurements. Information that may help explain variation in the correlation could come from knowledge of the variation in the building characteristics. For example, the literature review indicated that the architectural and mechanical characteristics of a building may affect building occupants' perception of their indoor environment. The literature review also indicated that those characteristics may effect occupant's perception of the sound environment even if the sound of the indoor comfort environment is not significantly affected.

The sound data analysis completed did not find any consistent correlation between the sound level data chosen and the corresponding questionnaire question. Thus, it was not shown that sound levels measured in a zone can be a good predictor of occupant perception of sound and its effect on performance. There can be several reasons for the inability to identify correlation. A root cause analysis of the problem "analysis failed to show that measured sound levels can be used to predict sound related occupant perceptions" was performed to help identify all the possible causes.

The possible causes identified were:

- There is in fact no correlation between measured sound levels and occupant perception of the effects of sound. This is not a cause because it is well documented in published literature that occupants are annoyed by high sound levels and such levels do affect productivity.

- The sound levels in the buildings did not reach a sufficient difference between zones such that occupants' perception would be sensitive to the differences. In that case, there was no correlation between measured sound levels and occupant perception of the effects of sound due to low variation between zones. None of the buildings were observed to consistently have sound at levels considered to objectionably outside the normal range for office buildings. In particular, within a building for nearly all cases measured differences between zones in significant sound levels (L_5 to L_90) were less than 6 dB. 6 dB is considered noticeable but well below twice as loud and may not normally be perceived as a large difference. However if a 6 dB or greater consistent difference actually existed between the zones, that can result in significant differences in occupants' perceptions between those zones. Therefore the limited variation in the measured levels cannot be considered the main cause of the inability to identify correlation.
- The measured sound levels used in the correlation were not the correct levels and other levels would have correlated with the perception questionnaire results. The sound levels used were based on engineering experience and judgment. However, other levels were not tried and may be better suited for the correlation. Therefore, this is a possible contributor in some correlations but not likely to be the cause of the inability to identify any consistent correlation.
- The questionnaire failed to capture the true perceptions of the occupants. The sound related questions were developed through a cooperative effort by sound engineers and perception questionnaire experts. The questionnaire no doubt introduced some experimental error but is unlikely to be the cause of the inability to identify any consistent correlation.
- Insufficient sample size of questionnaire respondents reduced the chances of identifying correlation. This certainly applies for some buildings where sample size was small. The way that data were correlated, the smaller the sample size, the harder to achieve a 95 percent confidence level in a positive correlation. This would have reduced the number of positive correlations but would not account for the absence of any consistent correlation.
- The sound level measured in the zone does not accurately represent the sound level in the immediate environment of the questionnaire respondent. In a typical building, a zone covered a large area, in some cases nearly 2000 square feet. Based on personal observation of the co-PI, and a study of the HVAC systems on a floor, the sound levels that exist in a zone over a distance of less than 50 feet can vary significantly, equal to or greater than the sound level variation that was measured between zones. However, the sound level that was used to represent a zone was measured in one area with two microphones separated by 10 feet on average. The location of the microphones was determined by the criteria covered in Section 3 which made the locations a reasonable cross-section of locations in the building but not for any zone. It is quite likely that for many buildings, sound level variation within a zone was often as high or higher than the zone-to-zone variation. An additional inaccuracy was introduced by the proximity of zones. Often a particular floor of an office building was divided into two or more zones that were contiguous. This resulted in cases where a respondent may actually be much closer to the microphones of the neighboring zone than those of their zone yet had their answer paired to the results from the latter. In statistical terms, the sample rate was two samples per zone, that were not independent but closely coupled, and thus there was only one independent sample per zone. Because of the known noise level variation within the zone, one independent noise measurement sample per zone is an insufficient sample size. Such an analysis is highly susceptible to a Type II error. Specifically, an analysis performed under these circumstances can easily fail to identify any existing correlation between actual sound levels and the occupants' perception of the effect of those levels. This is the dominant reason that the inter-zone comparisons failed to identify consistent correlation.

The failure to identify any correlation between inter-building zone sound levels and occupant perceptions does not preclude the existence of a correlation in general between sound levels and occupant perceptions. A comparison between buildings of the sound data suggest that buildings have similar variation in sound levels from one zone measurement station to the next but also have significant differences in average sound levels. Respondent data from different buildings also shows noticeable differences (Figures 1-10). It remains to be determined if the differences correlate.

The method of coupling questionnaire respondents with zone sound levels introduced sufficient error into the data to guarantee a failure to accurately identify any correlation between the measured sound levels and the questionnaire respondents' data. The physical characteristics of the sound in the buildings, in particular, the significant variation of sound levels within a zone, the contiguous locations of many zones and the lack of evidence of significant differences in the overall sound environment between the zones made the method inappropriate.

Although the measured sound levels do not accurately represent the respondents to whom they were paired, the levels may be representative of the sound environment in the building. Using six stations with a total of twelve microphones is below the desired number of samples to accurately represent the sound environment of a building yet it is much better than the sample of one location with two microphones used to represent a zone. Thus a building-to-building correlation analysis may yield useful results.

The correlation data for sound should be disregarded due to error introduced by the small sample size of only one independent sound measurement per zone. A building-to-building correlation analysis should be conducted to determine if sampling in a building can be used to accurately predict occupant perceptions about the sound environment and its effect on worker productivity.

Any follow-on studies need to decide how closely the study should tie a measured sound level to a questionnaire respondent. One choice is to colocate the microphones with the respondent so that the sound level measured has a high probability of being representative of the respondents' immediate environment. The other is to sample in sufficient numbers the sound environment in the area used in the comparison, and sample a sufficient number of occupants so that in the aggregate, the sound levels and their variation accurately represent the sound level environment in the area and the respondents answers accurately represent occupant perceptions.

5.5 LIGHTING

Significant differences in lighting measurements were observed for different buildings. However, the lighting measurements were not significantly different for different days for most of buildings, with only one exception. The overall illuminance at work surfaces of ten buildings was higher than the high end of the design range. Most of buildings had uniform lighting distribution at work surface. The three buildings with direct/indirect lighting systems had more uniform light distribution and lower variations. Luminance results greatly depended on the weather, window orientation and measurement time. The results provided in this study provide an indication with regards to luminances and variations from windows in a typical office building. Respones to lighting on the perception questionnaire were summarized in Figures 1-10. Results from the four productivity related questions in the questionnaire, it was found that: 1) most respondents believe that the quality of lighting is important to their productivity; 2) lighting levels and glare are the most important lighting factors that affect productivity; and 3) approximately a third of respondents think inappropriate lighting levels and too much glare affect their productivity.

5.6 LESSONS LEARNED

Through all stages of this research task lessons were learned by the investigators in regards to efficiency, accessibility, and communication. The following are items that can be used to improve the quality of further research of this type.

- Shipping the instrumentation and equipment used in this task posed a challenge because of its size and the purchase costs resulting in expenses for insurance. Instrumentation and equipment required two shipping pallets (Figure 13). Equipment traveling in such bulk needed to be scheduled for shipment at least 14 days prior to sampling. The investigators chose to send the equipment from sample location to sample location without having it shipped back to the university between locations. If all sampling trips were scheduled in advance, then the equipment only had to cross the country once instead of being shipped back and forth. Scheduling this way keeped shipping costs down because the distance traveled was much smaller and the time between field sampling was less. Therefore, a research location could be sampled every other week this way instead of once a month. However, the equipment could not be stored at a sampling location for an extended period of time. Shipping schedules should be made in advance and communicated to the shipping company as well as an employee at the pickup and the drop off locations.

Figure 13. Photograph of the two shipping pallets required for transport of the instrumentation and equipment for this task.

- The use of the VIVO probes for temperature, humidity, and draft took a great deal of time to set up, download, and disassemble. First, the set up of the VIVO meters required many small, tedious connections. Second, each of the six thermal comfort stationstook 20 minutes to download, for a total of two hours post-data collection just for downloading. If the research time frame was from 8am to 4pm, then the equipment was not boxed up and ready for the next shipment until 7pm at the earliest. Many buildings did not keep the doors open that late; security alarms could be activated. For other security reasons, the building administration may not want outsiders on the premises without supervision. Finally, as previously mentioned, the VIVO stations are time-consuming to disassemble as well. New Cabbage Cases were purchased to transport the VIVO equipment so that it would not have to be completely disassembled for every shipment. Yet, this might be a threat to the delicate nature of the instruments. Several probes needed repair after sampling trips.
- A recruiting trip by the liaison to the respective field location prior to the sampling trip was helpful in establishing a relationship with the building's employees. A meeting with the building manager was helpful for two main reasons. First, the manager knows the project on a more personal level. The liaison could discuss the logistics of what would be expected in a clearer manner with the manager as well as other administrative staff who might need to be aware of the project. They have opportunity to ask questions as they think of them instead of back and forth over email and missed telephone calls over the course of multiple months. Second, the liaison could view the environment of the building. Issues such as the building's shipping dock for unloading/loading the equipment, a refrigerator for storing the microbiological media, a quiet space/conference room to set up the perception questionnaire, and meeting the front desk staff are examples of steps that make the sampling team's time at the building smoother. As learned, sometimes building managers error in the accessibility of their respective building and do not know who needs to be made aware of this research prior to the sampling. The liaison can settle these issues prior to travel. Also, maps can be acquired and zone locations can be planned prior to traveling.
- The office building's administration must be active in recruiting for the perception questionnaire. If the administration does not encourage the employees to participate, then participation rates will be low. An active administration greatly increased the participation rate. Also, once word out out about the length of the questionnaire, the amount of participation dropped off if administrationwas not involved in the recruiting process.
- Space was limited within the zones for the tripods of equipment as well as minimal availability of electrical outlets. The team traveled with six extension cords and six power strips that had to be used in most of the offices. So, finding adequate power sources was sometimes a challenge.
- Finally, a timetable dictating technician responsibilities for setup, monitoring, and downloading was constructed. This helped structure the work periods and was a way to verify that nothing was skipped or overlooked. It also aided the field team in working more efficiently.

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APPENDIX A: QUESTIONNAIRES REVIEWED

This is a standard questionnaire developed by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). The questionnaire was used in three identical benchmark studies in San Francisco (USA), Townsville (Australia) and Montreal (Canada) referenced earlier.

1. Name
2. Date:
3. Time:

In this part of the survey we would like to know how you feel RIGHT NOW, at this moment.

4a. (Thermal environment) Please tick the scale below at the place that best represents how you feel at this moment. You may tick in an appropriate place between two categories, if you wish.

Cold	Cool	slightly Cool	Neutral	Slightly Warm	Warm	Hot

4b. Is the thermal environment acceptable to you? 1 ˆ unacceptable 2 ˆacceptable

4c. Please select the box below that best represents how you feel at this moment.
I would like to be:

3. ˆ Warmer 2. ˆ No Change 1. ˆ Cooler

5. Please select the boxes that best represent how you feel at the moment about the air movement in your office.

6 ˆ very acceptable
5 ˆ moderately acceptable
4 ˆ slightly acceptable
3 ˆ slightly unacceptable
2 ˆ moderately unacceptable
1 ˆ very unacceptable

I would like:

3. Í More Air movement
2. Í No change
1. Í Less Air movement

6. (General Comfort) How comfortable is your office right now?

6 Í very comfortable
5 Í moderately comfortable
4 Í slightly comfortable
3 Í slightly uncomfortable
2 Í moderately uncomfortable
1 Í very uncomfortable

7. (Temperature) What would you estimate the temperature to be Right now?

8. (Activity) What activities have you been engaged in during the preceding hour?

	Sitting quietly	sitting typing	standing still	on your feet working	driving a car	walking around
Last 10 minutes?	□	□	□	□	□	□
The 10 minutes preceding?	□	□	□	□	□	□
The 10 minutes before that?	□	□	□	□	□	□
The half hour before that?	□	□	□	□	□	□

9. (Clothing) Please indicate whether you are wearing any of the items listed below by circulating the appropriate number. 0 = not wearing item, 1 = light weight item, 2 - medium weight item, 3 = heavy weight item.

FEMALES:

Under layer:

0 1 2 3 top
0 1 2 3 bottom
0 1 2 3 slip

MALES:

under layer

0 1 2 3 top
0 1 2 3 bottom

Footwear:			
0 1 2 3	socks	0 1 2 3	socks
0 1 2 3	pantyhose	0 1 2 3	shoes
0 1 2 3	shoes		
Mid layer		**Mid layer**	
0 1 2 3	short sleeved shirt	0 1 2 3	short sleeved shirt
0 1 2 3	long sleeved shirt	0 1 2 3	long sleeved shirt
0 1 2 3	dress	0 1 2 3	pants
0 1 2 3	skirt	0 1 2 3	shorts
0 1 2 3	pants or slacks		
0 1 2 3	shorts		
Outer layers		**Outer layers**	
0 1 2 3	sweater	0 1 2 3	sweater
0 1 2 3	vest	0 1 2 3	vest
0 1 2 3	jacket	0 1 2 3	jacket

10. Please indicate whether you have consumed any or the flowing items within the last 15 minutes.

☐ Hot drink	☐ Caffeinated drink	☐ Snack or Meal
☐ Cold drink	☐ Cigarette	

11. Are you presently using air conditioning at home and/or or in your car?

	Compressor based air Conditioning		Evaporative air conditioning		Not available
	yes	No	Yes	No	
at home in my bedroom	☐	☐	☐	☐	☐
at home in my living area	☐	☐	☐	☐	☐
in my car	☐	☐			☐

A1. INDOOR BACKGROUND SURVEY QUESTIONS ASSOCIATED WITH THE ASHRAE SURVEY

1. Name: 2. Date:
3. Department or group:
4. Occupation:
5. Company name or organization
6. Work phone number: 7. Location in Building

8. How long have you lived in the "area"? Years Months
9. Are you using your home air-conditioner at this time of year?

1 Yes 2 No 3 not available

10. On the average, how many hours per week do you work at this job? Hour's at work
11. On the average, how many hours per day do you sit at your work area? Hours at desk
12. What is your approximate height? Centimeters
13. What is your approximate weight? Kilograms
14. What is your age? Years

Please tick the following

15. What is your gender? Male Female
16 Your ethnic background?

1 Native American
2 Asian or Pacific Islander
3 Hispanic
4 African American
5 Other (please specify:)

17. Is English your primary language? 1 Yes 2 No
18. What is the highest grade of school you completed?

1 ☐ school leaving certificate or less	5 ☐ university college bachelors degree
2 ☐ higher school certificate (Yr. 12)	6 ☐ some graduate school
3 ☐ some college	7 ☐ university higher degree
4 ☐ college diploma	8 ☐ PhD

Work Area Satisfaction

Using the scale below, please indicate how SATISFYING YOUR WORK AREA IS with respect to each characteristic by circling the number that reflects how you feel

6 very satisfied
5 moderately satisfied
4 slightly satisfied
3 slightly dissatisfied
2 moderately dissatisfied
1 very dissatisfied

(Circle one number for each item)

How satisfied are you with:

1.	The type and levels of sounds?	1	2	3	4	5	6
2.	The lighting?	1	2	3	4	5	6
3.	The temperature?.....	1	2	3	4	5	6
4.	The air quality?	1	2	3	4	5	6
5.	The ventilation and air circulation?	1	2	3	4	5	6
6.	The colors of walls or partitions?	1	2	3	4	5	6
7.	The furniture and equipment?.....	1	2	3	4	5	6
8.	The amount of space available to you?	1	2	3	4	5	6
9.	The level of privacy?	1	2	3	4	5	6
10.	The comfort of your chair?	1	2	3	4	5	6
11.	Provision of non-smoking work areas?	1	2	3	4	5	6

In terms of comfort, how acceptable is your office work area overall?(Check one below)

6 Î very acceptable
5 Î moderately acceptable
4 Î slightly acceptable
3 Î slightly unacceptable
2 Î moderately unacceptable
1 Î very unacceptable

Do you have any additional comments about the comfort of your office work area?

Personal Comfort

Please complete each of the following statements by checking the box that best expresses your personal feelings or preferences.

1. On average, I perceive my work area to be: (check one)

6 Î very comfortable
5 Î moderately comfortable
4 Î slightly comfortable
3 Î slightly uncomfortable
2 Î moderately uncomfortable
1 Î very uncomfortable

2. On average, I perceive the temperature of my work area to be: (disregarding the effects of air movement, lighting, and humidity)

6 Î very warm
5 Î moderately warm
4 Î slightly warm
3 Î slightly cool
2 Î moderately cool
1 Î very cool

3. On average, I perceive the air Movement of my work area to be: (disregarding the effects of air movement, lighting, and humidity. Answer on both scales.)

3 Î too much
2 Î just right
1 Î too little

6 Î very acceptable
5 Î moderately acceptable
4 Î slightly acceptable
3 Î slightly unacceptable

2 ☐ moderately unacceptable

1 ☐ very unacceptable

4. On average, I perceive the Lighting of my work area to be: (disregarding the effects of temperature, air movement and humidity)

6 ☐ very bright

5 ☐ moderately bright

4 ☐ slightly bright

3 ☐ slightly dim

2 ☐ moderately dim

1 ☐ very dim

5. On average, I perceive the humidity of my work area to be: (disregarding the effects of temperature, air movement, and lighting)?

6 ☐ very humid

5 ☐ moderately humid

4 ☐ slightly humid

3 ☐ slightly dry

2 ☐ moderately dry

1 ☐ very dry

Personal Control

To what extent are you able to control the environment of the office space where you usually work? For each question below make a check mark next to the statement that best expresses your personal feelings or behavior patterns.

1. HOW much control do you feel you have over the thermal conditions of your workplace? (Check one).

5 ☐ complete control

4 ☐ high degree of control

3 ☐ moderate control

2 ☐ slight control

1 ☐ no control

2. How satisfied are you with this level of control? (Check one)

6 Í very satisfied

5 Í moderately satisfied

4 Í slightly satisfied

3 Í slightly dissatisfied

2 Í moderately dissatisfied

1 Í very dissatisfied

3. Can you exercise any of the following options to adjust the thermal environment at your workplace? (Check Y = yes or N = no for each item)

1 Y Í N Í open or close a window

2 Y Í N Í open or close a door to the outside

3 Y Í N Í open or close a door to an interior space

4 Y Í N Í adjust a thermostat

5 Y Í N Í adjust the drapes or blinds

6 Y Í N Í turn a local space heater on or off

7 Y Í N Í turn a local fan on or off

4. In general, how often do you exercise any of the following options to adjust the thermal environment at your workplace?

6 always

5 often

4 sometimes

3 rarely

2 never

1 not available

(Circle one number for each item)

1. Open or close a window..... 1 2 3 4 5 6

2. Open or close a door to the outside..... 1 2 3 4 5 6

3. Open or close a door to an interior space..... 1 2 3 4 5 6

4. Adjust a thermostat..... 1 2 3 4 5 6

5. Adjust the drapes or blinds..... 1 2 3 4 5 6

6. Turn a local space heater on or off 1 2 3 4 5 6

7. Turn a local fan on or off 1 2 3 4 5 6

Job satisfaction

The questions below ask about different characteristics of your job. Please indicate how satisfying your job is with respect to each characteristic by circling the number that reflects how you feel:

6 very satisfied
5 moderately satisfied
4 slightly satisfied
3 slightly dissatisfied
2 moderately dissatisfied
1 very dissatisfied

How generally satisfied are you with: (Circle one number for each item)

1. Your job overall?..... 1 2 3 4 5 6
2. Your company's policies? 1 2 3 4 5 6
3. The degree of access to other people you work with? 1 2 3 4 5 6
4. The opportunity to develop your skills? 1 2 3 4 5 6
5. Your job security? 1 2 3 4 5 6
6. Your relations with your co-workers?..... 1 2 3 4 5 6
7. Your relations with your supervisors? 1 2 3 4 5 6
8. Your pay? 1 2 3 4 5 6
9. Your chances or advancement? 1 2 3 4 5 6
10. Your level of responsibility?..... 1 2 3 4 5 6
11. Your independence or autonomy?..... 1 2 3 4 5 6
12. The degree of recognition for good work?..... 1 2 3 4 5 6
13. Your interest in the work itself?..... 1 2 3 4 5 6
14. The quality of equipment you work with?..... 1 2 3 4 5 6

15. The time pressures of your job? 1 2 3 4 5 6

13. Your interest in the work itself?..... 1 2 3 4 5 6

14. The quality of equipment you work with?..... 1 2 3 4 5 6

15. The time pressures of your job? 1 2 3 4 5 6

Health Characteristics

Below are some symptoms that people experience at different times. Please indicate how often you have experienced each symptom in the past month by circling the appropriate number for the scale below

5 very often

4 often

3 sometimes

2 rarely

1 never

Circle one number for each symptom)

1. Headache..... 1 2 3 4 5

2. Dizziness..... 1 2 3 4 5

3. Sleepiness..... 1 2 3 4 5

4. Sore or irritated throat 1 2 3 4 5

5. Nose irritation (itch or running)..... 1 2 3 4 5

6. Eye irritation 1 2 3 4 5

7. Trouble focusing eyes 1 2 3 4 5

8. Difficulty concentrating 1 2 3 4 5

9. Skin dryness, rash or itch 1 2 3 4 5

10. Fatigue 1 2 3 4 5

11. Do you take over-the-counter or prescription medication that might influence your comfort while at work?

1 Ï Yes

2 Ï No

On the average:

12. How many cigarettes do you smoke per day? cigarettes

13. How many cups of caffeinated beverages do you drink per day? Cups per day

14. How many hours do you exercise per week? Hours

Your Environmental Sensitivity

A number of questions related to your typical response to environmental conditions are given below. To indicate your answer to a question circle the number from the following scale which best expresses how you typically feel.

6 very sensitive
5 moderately sensitive
4 slightly sensitive
3 slightly insensitive
2 moderately insensitive
1 very insensitive

Circle one number for each question

1. Do you tend to be SENSITIVE to environments which are

   Too noisy? 1 2 3 4 5 6

2. Do you tend to be Sensitive to environments which are

   Too hot? 1 2 3 4 5 6

3. Do you tend to be Sensitive to environments which are

   Too cold?..... 1 2 3 4 5 6

4. Do you tend to be SENSITIVE to environments which have

   Too little air movement? 1 2 3 4 5 6

5. Do you tend to be SENSITIVE to environments which have

   Too much air movement? 1 2 3 4 5 6

6. Do you tend to be SENSITIVE to environments which are

Too dimly lit?..... 1 2 3 4 5 6

7. Do you tend to be SENSITIVE to environment which are

Too bright?..... 1 2 3 4 5 6

8. Do you tend to be SENSITIVE to environments which have

Poor air quality? 1 2 3 4 5 6

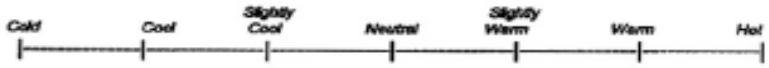
A2. SPAGNOLO AND DE DEAR, 1988 QUESTIONNAIRE.

Outdoor Thermal Comfort Questionnaire

NOTE: This questionnaire is entirely voluntary. If you do not wish to complete it, or any part of it, you are under no obligation to do so

Date: ___/___/___ Time: ___:___ am/pm Gender: Male / Female

Question 1: **TEMPERATURE**
Dressed as you are at the moment, please tick the scale to indicate how **YOU** currently feel.



Would you like to be (circle appropriate answer)?

Warmer *No change* *Cooler*

Question 2: **WIND**
Would you like (circle appropriate answer):

More air movement *No change* *Less air movement*

Question 3: **SUN**
Would you like (circle appropriate answer):

More sun *No change* *more shade*

Question 4: **CLOTHING**

Circle ALL the items closest to what you are wearing at this moment:

Shorts OR short skirt	*Jeans OR other long pants OR long skirt*
Jumper AND/OR Jacket	*Vest OR singlet top*
Short sleeved shirt	*Long sleeved shirt*
Shoes AND/OR socks	*Sandals OR thongs*

Are your clothes mainly LIGHT or DARK in colour (circle appropriate answer).

Question 5: **ACTIVITY**

For the last half hour have you been mainly (circle appropriate answer):

Sleeping *Sitting* *Standing* *Walking*

A3. NAKANO, ET AL., 2002 QUESTIONNAIRE

Q12. Please complete each of the following statements by checking the box that best expresses your personal feelings or preferences.

1) On average, I perceive my work area to be: (check one)
- ☐ comfortable
- ☐ slightly uncomfortable
- ☐ uncomfortable
- ☐ very uncomfortable

2) On average, I perceive the TEMPERATURE of my work area to be:
(disregarding the effects of air movement, lighting and humidity)
- ☐ hot
- ☐ warm
- ☐ slightly warm
- ☐ neutral
- ☐ slightly cool
- ☐ cool
- ☐ cold

3) How do you prefer the temperature to be?
- ☐ warmer
- ☐ no change
- ☐ cooler

4) Do you feel any AIR MOVEMENT in the work area?
- ☐ Yes ☐ No

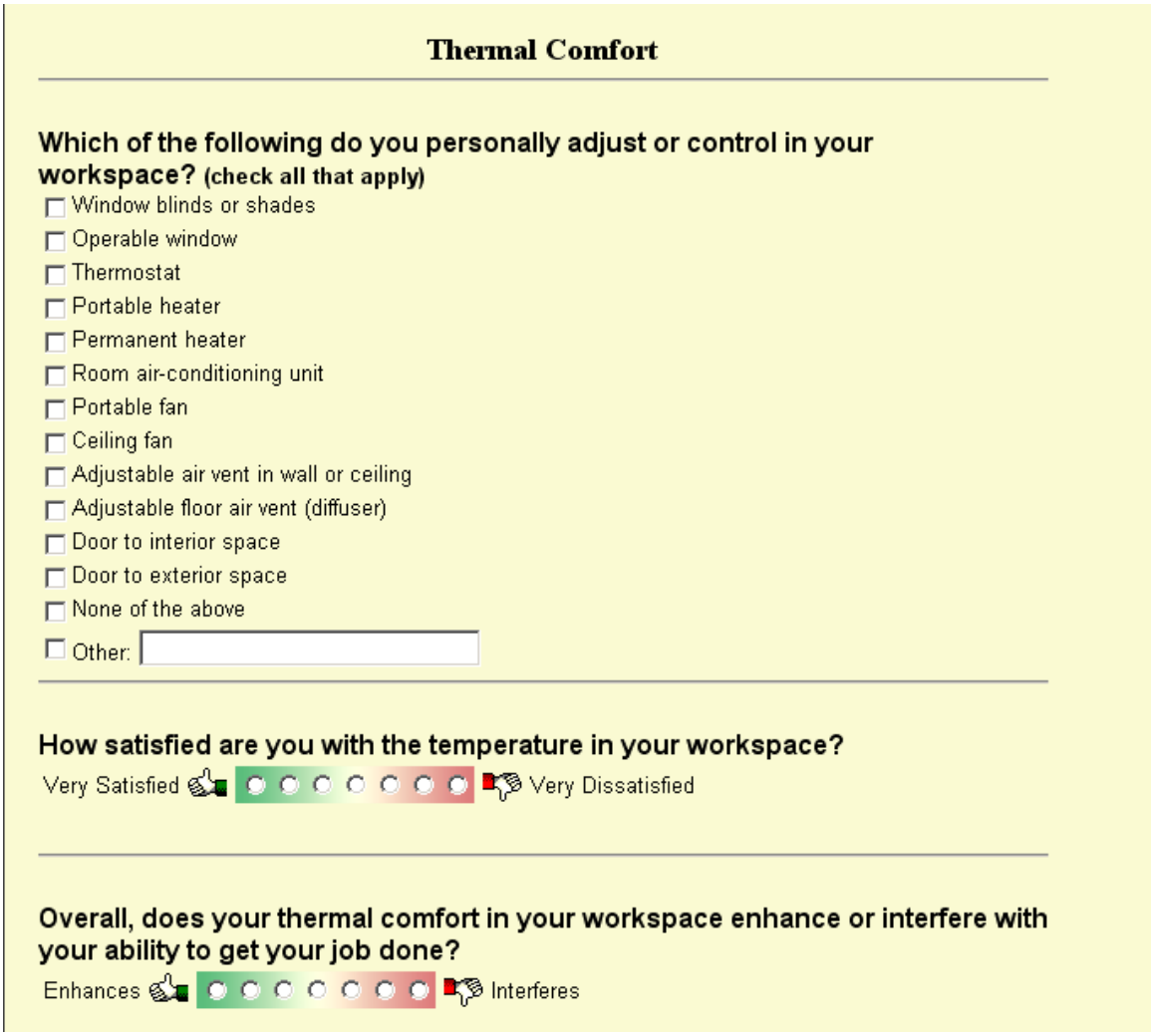
5) If yes, do you find the AIR MOVEMENT uncomfortable?
- ☐ Yes ☐ No

6) On average, I perceive the HUMIDITY of my work area to be:
(disregarding the effects of temperature, air movement and lighting)
- ☐ very humid
- ☐ slightly humid
- ☐ neutral
- ☐ slightly dry
- ☐ very dry

Q13. Below are some symptoms that people experience at different times. Please indicate how often YOU HAVE EXPERIENCED EACH SYMPTOM IN THE PAST MONTH by circling the appropriate number from the scale below. (Please circle one number for each symptom)

		Never				Very often
a)	Headache	1	2	3	4	5
b)	Dizziness	1	2	3	4	5
c)	Sleepiness	1	2	3	4	5
d)	Sore or irritated throat	1	2	3	4	5
e)	Nose irritation (itch or running)	1	2	3	4	5
f)	Eye irritation	1	2	3	4	5
g)	Trouble focusing eyes	1	2	3	4	5
h)	Difficulty concentrating	1	2	3	4	5
i)	Skin dryness	1	2	3	4	5
j)	Skin rash or itch	1	2	3	4	5
k)	Fatigue	1	2	3	4	5
l)	Unpleasant Odor	1	2	3	4	5

A4. CENTER FOR THE BUILT ENVIRONMENT SURVEY



Thermal Comfort

Which of the following do you personally adjust or control in your workspace? (check all that apply)

- ☐ Window blinds or shades
- ☐ Operable window
- ☐ Thermostat
- ☐ Portable heater
- ☐ Permanent heater
- ☐ Room air-conditioning unit
- ☐ Portable fan
- ☐ Ceiling fan
- ☐ Adjustable air vent in wall or ceiling
- ☐ Adjustable floor air vent (diffuser)
- ☐ Door to interior space
- ☐ Door to exterior space
- ☐ None of the above
- ☐ Other:

How satisfied are you with the temperature in your workspace?

Very Satisfied ○ ○ ○ ○ ○ ○ ○ Very Dissatisfied

Overall, does your thermal comfort in your workspace enhance or interfere with your ability to get your job done?

Enhances ○ ○ ○ ○ ○ ○ ○ Interferes

APPENDIX B: BUILDING SELECTION CRITERIA

Criterion	Inclusion	Exclusion	Comments
Location(s)	One major city in each of 5 selected geographic regions in US (NW, SW, MW, NE, SE).	Location in heavily polluted area (noise, particulate, odors from adjacent facilities).	If the city is a state capital, there is a higher likelihood of recruiting state government buildings. In some cases, it may be necessary to extend buildings to 2 cities within a region.
Age (construction completion date)	≥1989.	<1989; building may have been previously occupied by another owner/tenant, but if information is not available, this should be an exclusion criterion.	This ensures buildings will have a modern construction and ventilation system, no asbestos, and relatively modern furnishings. A range of 15 years is sufficient to stratify into three 5-year categories for analysis of age as a confounding variable on various outcomes. The building may have additions or remodeling after initial construction date.
Type/function	All office/non-manufacturing; single building or campus; government; business-administrative; may be open to the public but not a public facility per se.	Hospitals/health care facilities; schools (non-university); prisons; casino/hotels; museums/ theatres/other primarily public facilities; any mixed residential usage.	The exclusion criteria are designed to avoid uncontrollable confounding variables inherent to the building function as opposed to structure/operation. Subsequent studies may incorporate some of the excluded list with more specific protocols. The mix of government vs. private will not be fixed, but ideally no more than 33-50% government. A manufacturing facility can be attached but not directly connected to the same ventilation system.
Number of employers in building	Preferably one, but multiple divisions of same agency or employer is acceptable.	Multiple employers (>3).	Logistical constraints of recruitment.
Number of floors	One or multiple.		Multiple floors preferred so that floors can be randomly selected for testing.

Criterion	Inclusion	Exclusion	Comments
Number of occupants	≥75 full-time occupants.	<75.	The perception questionnaire has time constraints. This quantity increases the number of potential participant buildings (vs. Bluyssen cutoff of 125). For buildings with >20 occupants, a random selection of respondents in building or within target floors will be conducted. Ideally a range of occupant numbers between 75 and 500 will be identified. Building type distribution does not need to be equal in each city.
Time in building	≥75% of occupants spend at least 75% of their time in the building, 5 days per week. "Full-time" = 30+ hrs/week. Building may operate during normal business work-week or 24/7.		This ensures a stable occupant population for whom meaningful perception questionnaire can be obtained.
Information	Building must have a manager or other individual who is familiar with its operating history, maintenance records, layout, floor plan, HVAC, and IAQ issues. Energy usage and maintenance cost information must be available.		
Ventilation	Mechanically ventilated (central).	Operable windows; non-central ventilation.	Reflects building stock that will be relevant to our study for future data usage. Parking in basement is acceptable.

Criterion	Inclusion	Exclusion	Comments
Building history		History of: significant construction or design defects; significant water intrusion or mold problems that have required formal remediation (minor leaks that were immediately repaired are acceptable); significant insect/pest, particulate, or gas contaminants; systematic or recurrent occupant health complaints that have required formal IEQ investigation or workers' comp claims; recurrent or systematic complaints of odors or climate problems; major ventilation repairs due to malfunction (scheduled maintenance is acceptable)	These exclusion criteria maximize the likelihood of obtaining truly non-problem buildings. No significant OSHA violations or litigation related to any of the exclusion criteria
Smoking		Smoking permitted anywhere in building (preferably since building has been open, but at least 75% of its operating age)	This ensures that smoking is eliminated entirely as a confounding variable for building and occupant perception. Virtually all buildings in US today prohibit smoking.
Resources	At least one designated person is available onsite to coordinate logistics. Designee must have access to computer and internet. Space is available on-site to conduct questionnaires. Must commit to recruiting 75% of all or randomly selected occupants to participate in questionnaires.		
Employee representation	Unions encouraged.		

APPENDIX C: BUILDING SELECTION QUESTIONNAIRE

Criterion	Questions	Responses[1]
Contact	N/A	Name, phone, address, email of contact (text)
Location(s)	In which city is the building located?	List of cities and states
Age (construction completion date)	In what year was the building opened for occupancy?	Year
	Has the building undergone any major additions?	Yes/No-Text
	Has the building undergone any major remodeling?	Yes/No-Text
Type/function	What is the primary function of the operations in the building?	Administrative; government; other
Number of employers in building	Is there a single employer in the building?	Yes/No
	If no, how many different employers?	Number; text (describe)
Number of floors	How many occupied floors are in the building?	Number (min. = 1)
	Is there more than one building?	Yes/No-if yes, list number
Number of occupants	How many occupants work full time in the building?	Number (actual or estimate)
Time in building	Do at least 75% of occupants spend at least 75% of their time in the building?	Yes/No
	Do all employees have the same work week?	Yes/No
	What are operating hours of the building (not when open, but when occupied)?	Select (MF 8-6; second shift; 24/7)
Information	Is there a manager or other individual who is familiar with its operating history, maintenance records, layout, floor plan, HVAC, and IAQ issues?	Yes/No—List name, phone, email address
	Is energy usage and maintenance cost information available to us in advance of the study?	Yes/No—Comments (text)
Ventilation	Is the building mechanically ventilated?	Yes/No—list type (VAV, etc.)
Building history	Does the building have any history of • significant construction or design defects? • significant water intrusion or mold problems that have required formal remediation (minor leaks that were immediately repaired are acceptable)? • significant insect/pest, particulate, or gas contaminants? • systematic or recurrent occupant health complaints that have required formal IAQ investigation or workers' comp claims? • recurrent or systematic complaints of odors or climate problems? • major ventilation repairs due to malfunction (scheduled maintenance is acceptable)?	Yes/No—Comments (brief description, year, response, outcome)

Criterion	Questions	Responses2
Smoking	Is smoking permitted anywhere inside the building?	Yes/No
Resources	Is there at least one designated person who is available onsite to coordinate logistics?	Yes/No—Comments
	Does this person have access to computer and internet?	Yes/No—Comments
	Is there adequate space available on-site to conduct questionnaires?	Yes/No—Comments
	Is client capable and willing to recruit 75% of all or randomly selected occupants to participate in questionnaires?	Yes/No—Comments
Employee representation	Are employees represented by a union?	Yes/No—Name of union

[1] If exclusion criterion is met, continue questions if criterion is not absolute for exclusion. Data on building selection need to be maintained in this exercise for documentation and analysis of building selection methods.

APPENDIX D: BUILDING CHARACTERIZATION QUESTIONNAIRE

Building Characteristics: Location: _____; Bldg # _____

1. The number of floors in the building is:

One	Two	Three	Four or more
1	2	3	4

2. The building was constructed after 1990:

Yes	No
1	2

3. Is the building oriented on a North/South axis:

Yes	No
1	2

4. The building's major glass areas face (check all that apply):

East	West	North	South	Equally
1	2	3	4	distributed
Northeast	Northwest	Southeast	Southwest	9
5	6	7	8	

5. The total area of windows on each orientation is:

North:	East:
South:	West:

6. The building construction type is (choose only one):

-Heavy masonry material (e.g. cement block, poured cement, or stone facing)	1
-Framed walls with exterior sheathing (e.g. wood, metal)	2
-Insulated masonry-type panels	3

7. The total roof area is: _____

8. The building has a flat type roof:

Yes	No
1	2

9. The building has a light-colored reflective roof coating:

Yes	No
1	2

10. The building's windows have a low E type insulated glass:

Yes	No
1	2

11. The window system of the building is capable of reducing solar penetration by:

Awning Technique	Shading Technique	Tinted Technique
1	2	3

12. The R-value of the building's roofing system in regards to the current standard required by the local building energy code is:

Not Met	Met	Exceeded	Don't Know

13. The specific R-value for the roofing system is: _____

14. The R-value of the insulation installed in the perimeter walls in regards to the current standard required by the local building energy code is:

Not Met	Met	Exceeded	Don't Know

15. The specific R-value for the perimeter walls is: _____

16. The building's HVAC system is controlled by an Energy Management Control System (EMCS) other than energy saving thermostats:

Yes	No
1	2

17. If yes, it is: If "Set Back", the schedule is:

Set Back	Turn Off
1	2

18. The building has an EMCS and the system is programmed to turn-off non-essential equipment on a 24/7 type operating schedule:

Yes	No
1	2

19. The EMCS is used for electrical demand limiting:

Yes	No
1	2

20. If the building **does not** have an EMCS, are there programmable energy saving thermostats:

Yes	No
1	2

21. If there are controllable thermostats in offices, the thermostats are enclosed in tamper-proof covered boxes**:**

Yes	No
1	2

22. The type of office is:

Cubicles	Enclosed	Mixed	Other
1	2	3	4

23. The majority size of offices is:

Less than 50 sq. ft.	50-100 sq. ft.	More than 100 sq. ft.
1	2	3

24. The typical shape an office is:

Square	Rectangular
1	2

25. Types of surfaces used in the offices are: (check all that apply)

Carpet on permanent floor	Carpet on raised floor	Matted	Vinyl/linoleum
1	2	3	4

26. The heights of the ceiling in the offices are:

less than 10 feet	10 feet or greater
1	2

27. The types of ceiling surfaces in the offices are: (check all that apply)

cement/structural	acoustical tile/ hung ceiling	drywall/sheetrock	hard surface cathedral
1	2	3	4

28. These fixed outdoor sound sources are from:

air handling equipment	motor/engines	wind on building	construction	other
1	2	3	4	5

29. Sources of sound from transportation are from:

highways	railways	airplanes	other
1	2	3	4

30. Sources of sound within the building, but outside of the work area are:

pumps/ motors on floor	activity above	conversations in adjacent rooms	plumbing/ air handler	other
1	2	3	4	5

31. Sources of sound within the work area are:

copiers/fax machines	computers	conversations	air conditioning	speech-masking system
1	2	3	4	5

32. Do work areas have background music?

Yes	No
1	2

33. There are self-contained roof top or mechanical equipment room units?

Yes	No
1	2

34. The type of control system used in the building is:

Variable Air Volume (VAV)	Constant Air Volume (CAV)	VAV&CAV	Dual Duct
1	2	3	4

35. The type of supply registers used in the building is:

Ceiling diffusers	Linear diffusers	Other
1	2	3

36. The type of return air flow system in the building is:

Plenum type	Ducted type
1	2

37. The Heating, Ventilation, and Air Conditioning system is:

A chilled-water type system with cooling towers	1
A chilled-water type system with air cooled	2
A packaged roof-type	3
A wall-mounted unit	4
A hydronic (radiator) system with mechanical ventilation	5

38. The energy performance of the chiller in kW/Ton is:

0.8- 0.7	0.7- 0.6	0.6- 0.5
1	2	3

39. The building has a thermal storage system:

Yes	No
1	2

40. There are small self-contained water-source heat pumps within the rooms:

Yes	No
1	2

41. There is a use of an economizer cycle:

Yes	No
1	2

42. The air distribution system is

Ceiling Air Distribution (CAD)	Under floor air distribution (UFAD)	Both
1	2	3

43. The type of control system the building has is:

Direct Digital control (DDC)	Pneumatic control
1	2

44. The filters are installed in the buildings HVAC units and are regularly replaced in adherence with a preventive maintenance schedule:

Yes	No
1	2

45. The building has a:

boiler with standard efficiency	1
boiler with high efficiency	2
furnace with standard efficiency	3
furnace with high efficiency	4
packaged air-conditioning w/ gas pack heater	5

46. The type of light fixtures is:

Diffusers	Parabolic
1	2

47. The type of lighting used is:

Indirect	Direct
1	2

48. There is a usage of task lighting:

Yes	No
1	2

49. The type of lighting used for general purposes is:

Incandescent	Magnetic core ballasts/ T-12	Electronic core ballasts/ T8
1	2	3

50. The average installed load including ballast in offices is:_____ w/ft2

51. The voltage for office lighting system is: (Choose all apply)

277V	1
208V	2
120V	3

52. The lighting control methods used in the offices are: (Choose all apply)

Manual Switching	1
Timing Device	2
Occupancy Sensors	3
Photosensors	4

53. What is the regular cleaning schedule for luminaries: _____

54. Luminaries were last cleaned: _____

55. The lamp replacement is:

on burnout	1
on group replacement	2

56. If the lamp is on group replacement, what is group replacement interval? _____

APPENDIX E: THERMAL COMFORT SENSORS

E1. DESCRIPTION OF SENSORS

Thermal comfort engineering data were collected using VIVO sensors with tiltable arms mounted on a movable, telescoping stand (Figure E1).

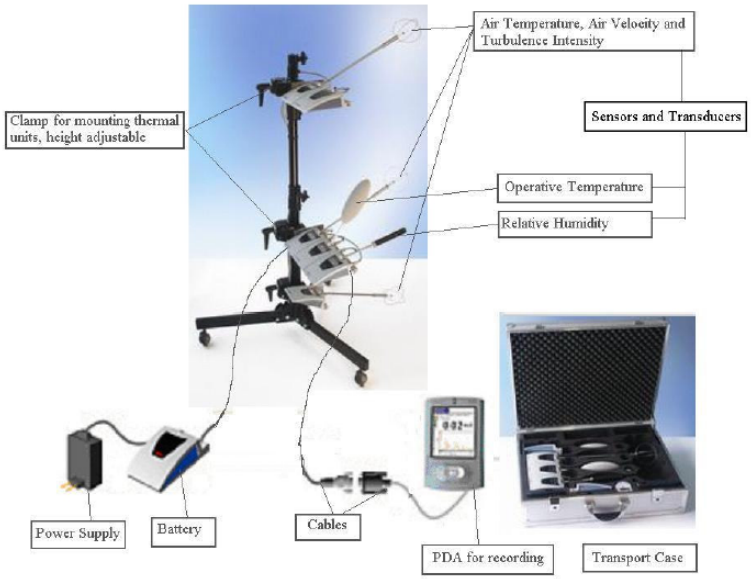


Figure E1. Schematic diagram based on the VIVO sampling cart and related hardware (assembled from VIVO/Dantec information on line).

A single operative temperature sensor (Figure E2) measured the operative temperature, a measure of the temperature experienced by a person as a result of the actual temperature, convection, and the effects of radiant heat. The unit provides a very close representation of the body's perception of temperature.

Figure E2. VIVO operating temperature sensor.

A single relative humidity (RH) sensor (Figure E3) used a capacitive sensor that measures the relative humidity as a percentage (range 0-100). This unit also had a sensor to measure air temperature.

Figure E3. VIVO relative humidity sensor

Three draught sensors (Figure E4) measure low air velocity and air temperature using omnidirectional, spherical, thin-film sensors. The unit's measurement range for velocity was 0.05-5 m/s; it measured fluctuations up to 2 Hz in air velocity.

Figure E4. VIVO draught sensor

The accuracy of VIVO sensors come reasonably close to the accuracy range recommended by ASHRAE 55 (Table E1).

Table E1. Difference between accuracy of VIVO sensors and those stipulated in ASHRAE Standard 55

Type of measurement	Unit of measurement	Range of measurement	ASHRAE standard	VIVO accuracy
Air temperature	°C	0-45°C	±0.2°C	±0.5°C
Air velocity	m/s	0.05-1 m/s	±0.05 m/s	±0.01 m/s
Operative temperature/ mean radiant temperature	°C	0-45°C	±0.2°C	±0.5°C
Relative humidity	%	0-100%	-	-

E2. STANDARD OPERATING PROCEDURE FOR VIVO IEQ INSTRUMENTS (PREPARED IN PART WITH INFORMATION FROM THE VIVO INSTRUCTION MANUAL)

Experienced users may move directly to secrtion E2.2 Recommended Installation Of Testing Station

Please note that field applicability can override these recommendations.

Important! Read this before you use the VIVO units.

Read all instructions carefully before installation and use. Connect units to only one platform at a time – either PC or Palm Pilot. Do not use the VIVO Battery as a communication unit, either with cable or infrared. Use only original cables. Avoid all kinds of moisture.

Warning! Connecting cables while power is ON may cause permanent damage to VIVO units. Always disconnect power before a cable is connected or disconnected. The VIVO units must be stored within the temperature range –20°C to +45°C. If stored outside of this interval the lifespan of the units will be significantly reduced.

The VIVO Battery has a built-in overload protection. Always use original Dantec replacement parts. This unit contains both a Lithium-ion and a Ni-MH rechargeable battery. When exposed to temperatures above 60°C (140°F) battery cells could explode or vent, posing a risk of fire. The batteries may also be damaged if the unit is exposed to excessive mechanical shocks. If the batteries are damaged, electrolyte may leak from the unit and cause personal injury. Keep the unit away from children.

This unit must not be disposed of in fire or with the normal household waste. Before disposal, the rechargeable batteries must be removed from the unit and delivered to the nearest battery deposit site according to local regulations. Contact the local waste disposal agency for the address of the nearest battery deposit site.

E2.1 Set-up of VIVO Instruments

Four units are used for measuring thermal comfort: VIVO Draught, VIVO Temperature, VIVO Humidity and VIVO Battery.

The following characteristics are common to VIVO instruments:

- A display showing the unit's status.
- A power indicator and infrared communication port.
- A mechanical arm for positioning the unit's sensor.
- A female connector, used when combining several units.
- A female connector for mechanical mounting bolt, used when combining several units.
- A plug for connecting units in a network.
- A mechanical wheel, used to turn mounting bolt.
- A mounting bolt.
- A plug for the power supply.
- A male connector, used when combining several units.

The VIVO base is illustrated in Figure E5.

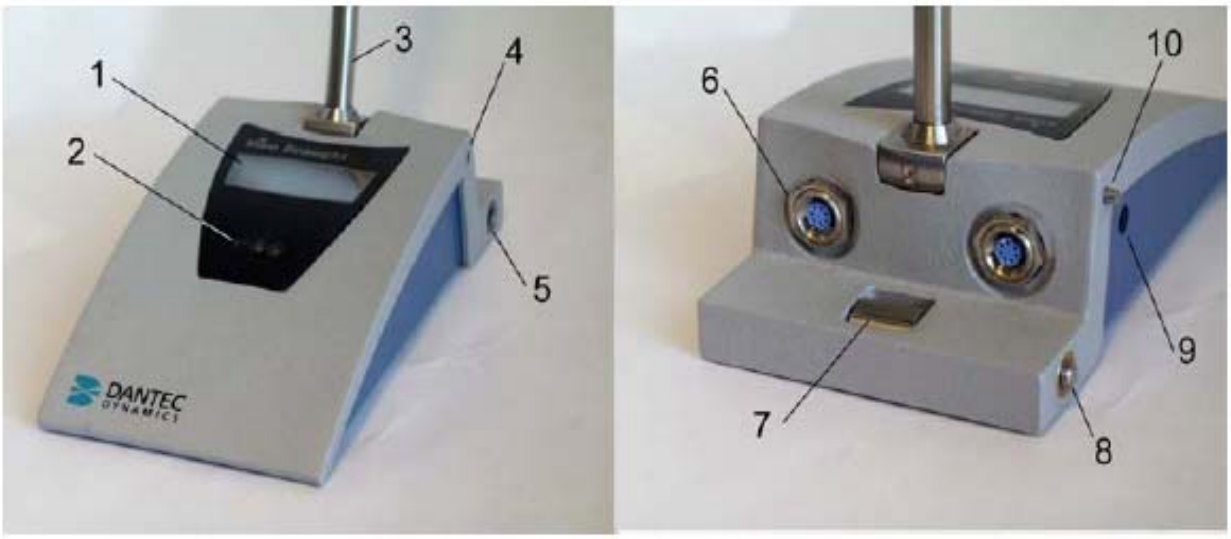


Figure E5. VIVO base

VIVO Temperature

VIVO Temperature measures the operative temperature, which is a measure of the temperature experienced by a person as a result of the actual temperature, convection, and the effects of radiant heat. The unit provides a very close representation of the body's perception of temperature. In the vertical position the unit represents a standing person, at an angle of 30o it represents a sitting person and when it is horizontal it represents a person reclining.

VIVO Humidity

VIVO Humidity measures the relative humidity of the air and the air temperature.

VIVO Draught

VIVO Draught is capable of measuring air velocities in the range 0 to 1 m/s (type 01) or 0 to 5 m/s (type 02). Both types also measure air temperature.

VIVO Field Control

VIVO Field Control (Figure E6) is a hand held PDA that helps interface between the sensors to randomly intermittently check the values of various thermal indices.

Figure E6. VIVO Field control.

To connect two VIVO Temperature units (see Figure E7):

1. Press the two units together so the male and female connectors meet.
2. Turn the mechanical wheel until the two units are locked securely together.
3. Connect the units with the network cable. Note that the arrow on the cable must line up with the arrow on the connector.
4. When the cable has been plugged in, turn the cable's metal ring clockwise until the cable is locked in the connector.

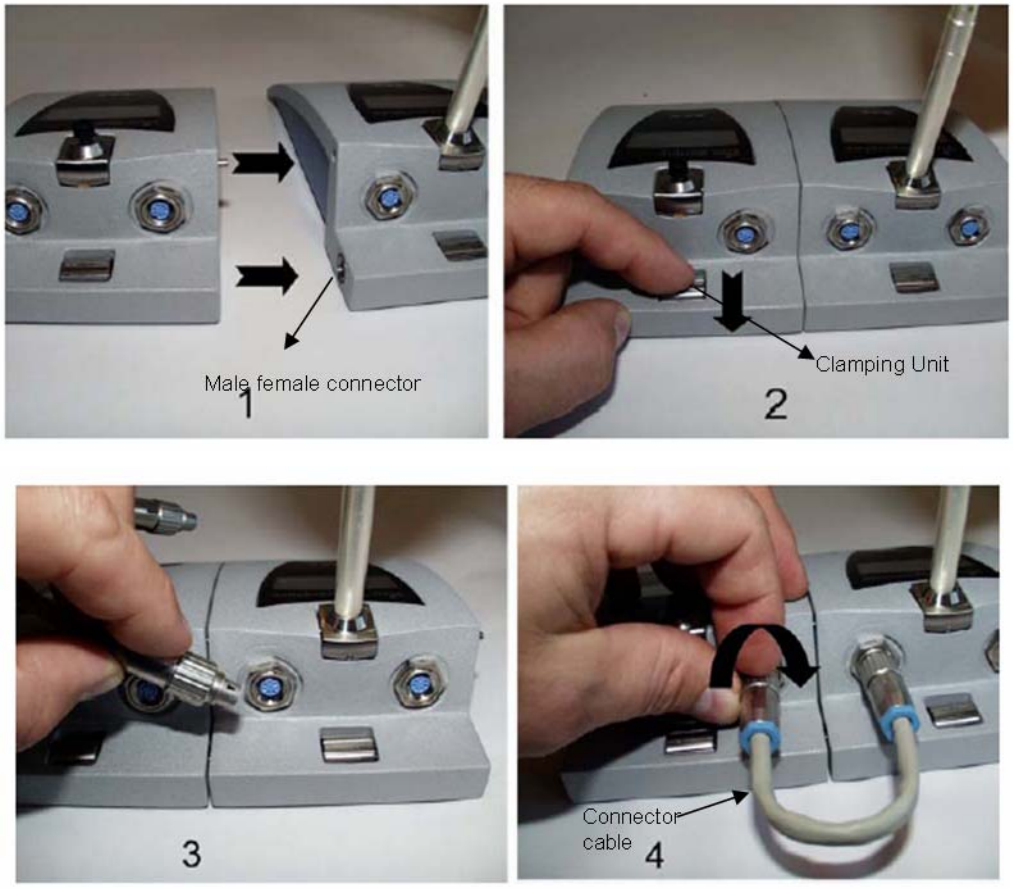


Figure E7. VIVO connection assembly sequence

None of the sensors should be touched, as that will affect precision. The mechanical arm can be adjusted by moving it up or down (Figure E8). The arm can be positioned from 0° to 90°, with fixed notches at 0°, 30° and 90°. Change the positions by using the arm alone. **DO NOT USE OR TOUCH THE SENSOR** for positioning**.**

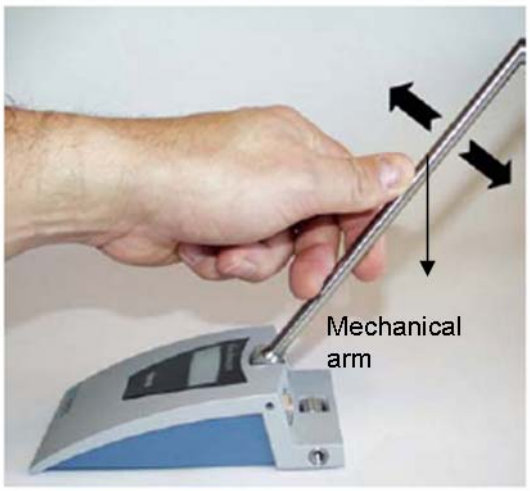


Figure E8. Positioning of the mechanical arm

The VIVO Draught instrument is different from the thermal sensors as it has a protective cover (cap) that has to be removed before the usage of the sensor. Lower the protective cap by turning the screw counter-clockwise to release it (Figure E9). When the cap has been lowered, tighten the screw again.

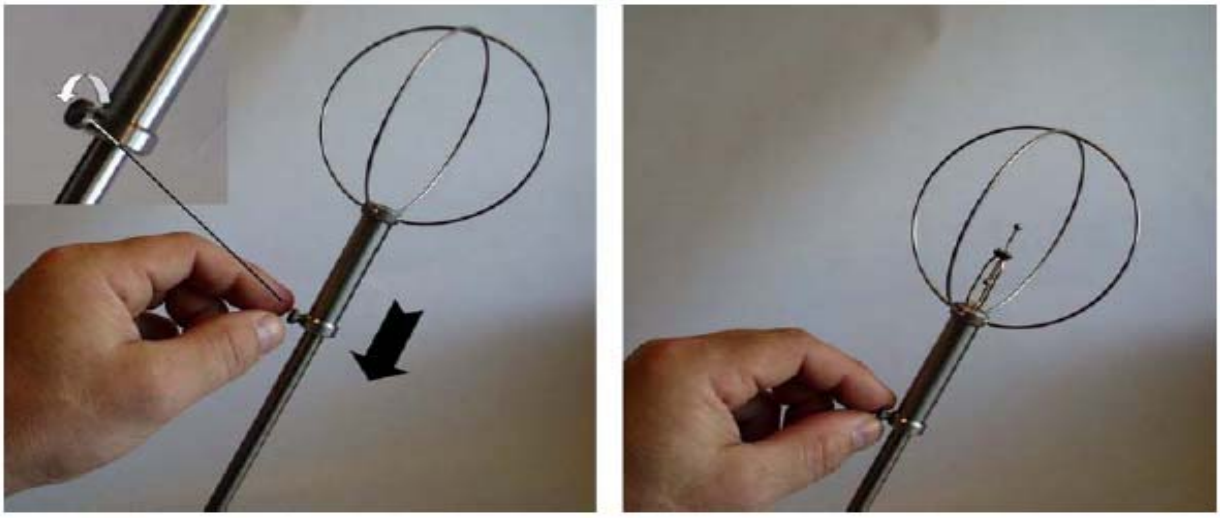


Figure E9. Hollow shaft of the VIVO Draught

VIVO units are mounted on a stand using a clamp (Figure E10) that can grip rounded items with a diameter of 13 to 55 mm. The units can be mounted on the clamp using the mounting bolt and a male connector (Figure E11).

Figure E10. Clamping unit for VIVO stand

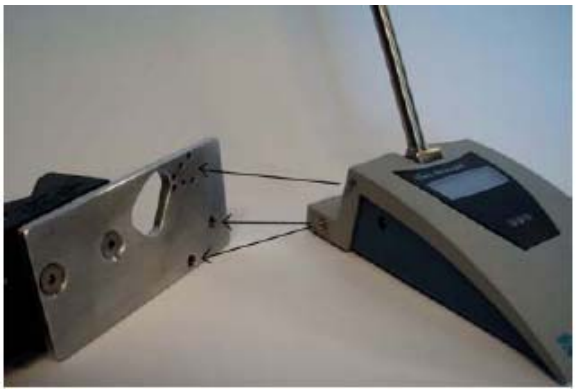


Figure E11. Mounting holes for clamping unit

Using different mounting holes makes it possible to mount the units at different angles. There are 2 places where the mounting bolt can be secured and 6 locations for the male connector (Figure E12).

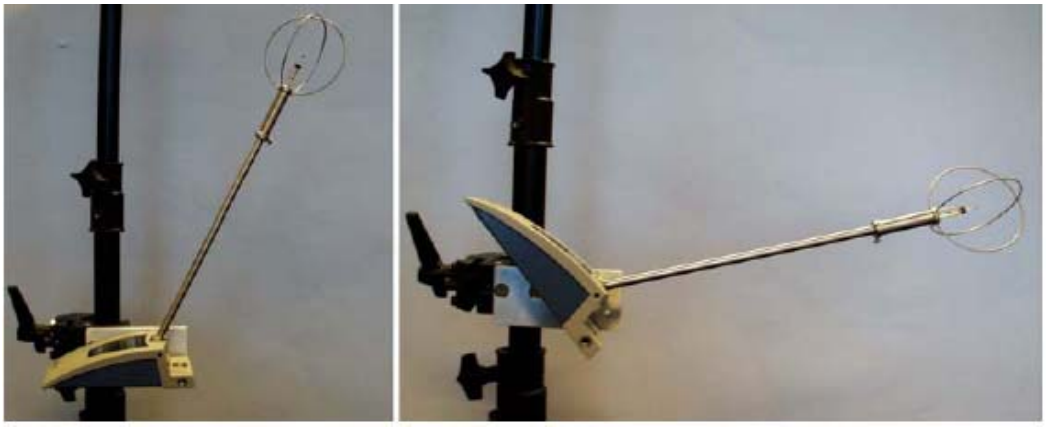


Figure E12. Locations of mounting bolts.

Either a current feed or a VIVO battery can be used as the power supply. Connect the current feed to the 220 V or 110 V electricity mains.

Before starting a measurement, check that all cables are connected and that the battery is fully charged.

Starting a measurement using a PDA:

1. Switch the PDA on. Select the VIVO icon.
5. Check that it has the desired time set-up. Select the synchronize button.
6. Synchronization starts automatically. It is finished when the program says that it is ready.
7. Synchronization can be stopped by pressing the Cancel icon.
8. If units are not interconnected, you must synchronize them individually.
9. Measurement starts automatically. Measurement finishes with an acoustic signal and a message: "Status is finished."
10. When the measurement is finished, the units are resynchronized.

A Screen shot of the PDA is illustrated in Figure E13.

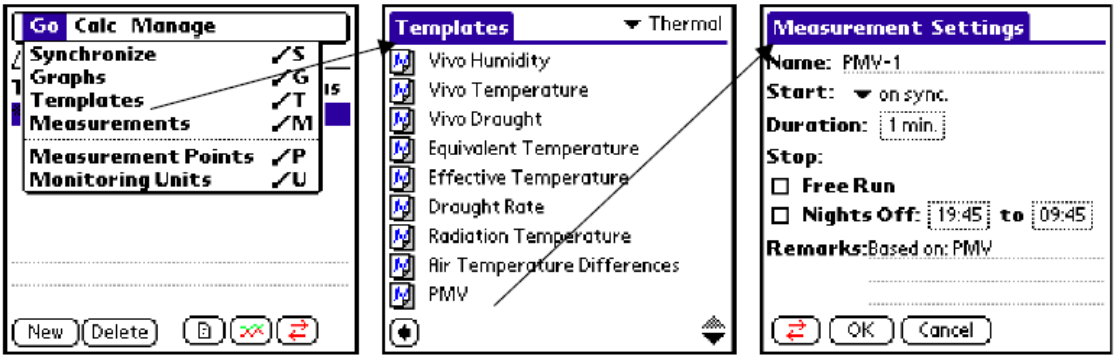


Figure E13. Screen shot of the PDA.

To maintain accuracy, it is mandatory for to check the output of sensors at regular intervals to see if it is within the expected range. Results can be checked periodically using the PDA as an interface. Connect a cable between the PDA and the VIVO assembly (Figure E14).

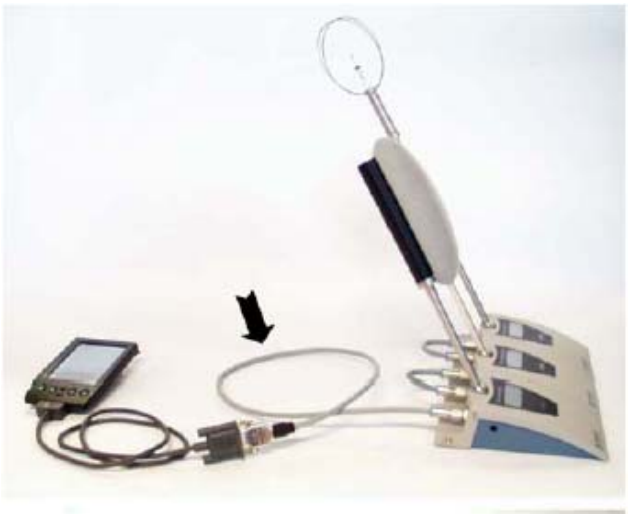


Figure E14. VIVO assembly with connection to PDA

When a measurement is finished, the PDA will beep 4 times. Confirmation of this is displayed with the finished measurements in the "Pending" folder. The measurement data will be transferred to the PDA on synchronization and any new measurement set-up will be transferred to the VIVO units at the same time.

If the measurement consists of data from several VIVO units that have not been interconnected during the measurement, you must synchronize with each unit individually.

After synchronization with all units, the measurement is moved from the "Pending" folder to the "Inbox" folder (Figure E15).

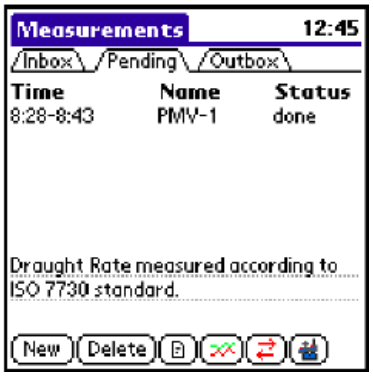


Figure E15. Screen shot of PDA Inbox

E2.2 Recommended Installation Of Testing Station

Please note that field applicability can override these recommendations!

The sensors on the six stationary carts and one movable cart are positioned at three different heights 0.1m, 0.6m and 1.1m for seated occupants. The six stationary carts are placed in a representative location in the room studied and operated for 8 hours in that location. A suggested layout can be found in Figure E16.

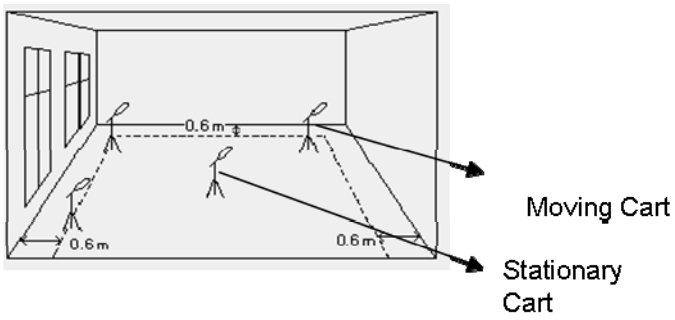


Figure E16. A representation of the geometric location of the monitoring stands in an office building

The battery has an output which can be connected to any one of the sensors. Make sure that the VIVO draught sensors (at all the three heights) are out of the shaft before starting to record any data. Once the sensors are setup, the display should record the sensors' serial number, location of the instrument, and position of the occupant (seated or standing). This is an indication that the sensors and the connections have been properly made. After this is done, the output cable from the sensors is plugged to the laptop using the RS 232 cable.

E2.3 Collecting VIVO Data Using Laptop

There are two programs (VIVO Explorer and VIVO Controller). VIVO Explorer is used for monitoring the unit and to verify that the instrument is operating properly. Figure E17 is a screen shot of the VIVO Explorer. Make sure that the correct communication port (COM1) is used.

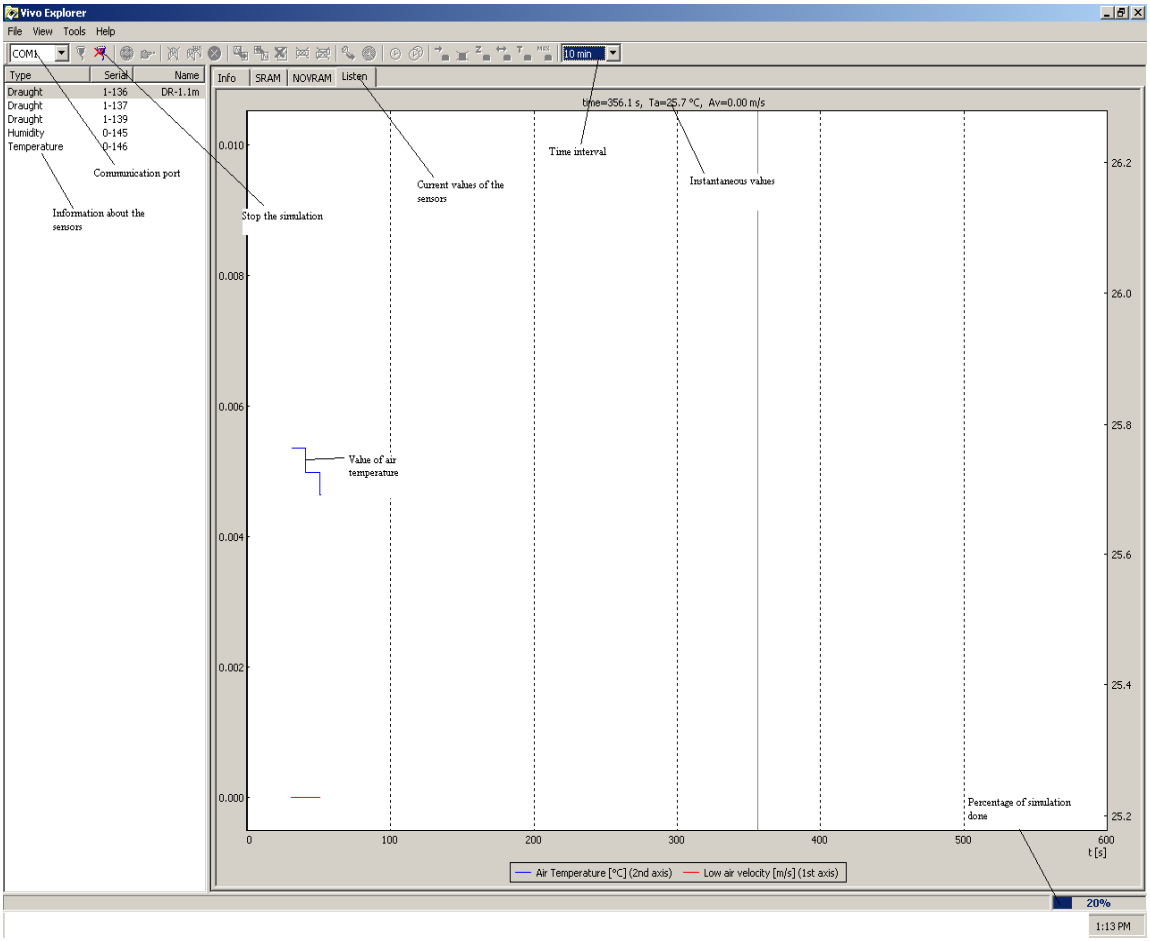


Figure E17. Screen shot of the VIVO Explorer

The second program, the VIVO Controller, is the most important one. This is the program that helps download the data from sensors to the laptop.

To download data:

1. Install the VIVO Controller software in the laptop. Only install the software once.
2. From the Start Menu, select Programs/Dantec/VIVO controller. Figure E18 illustrates the screen as it appears.

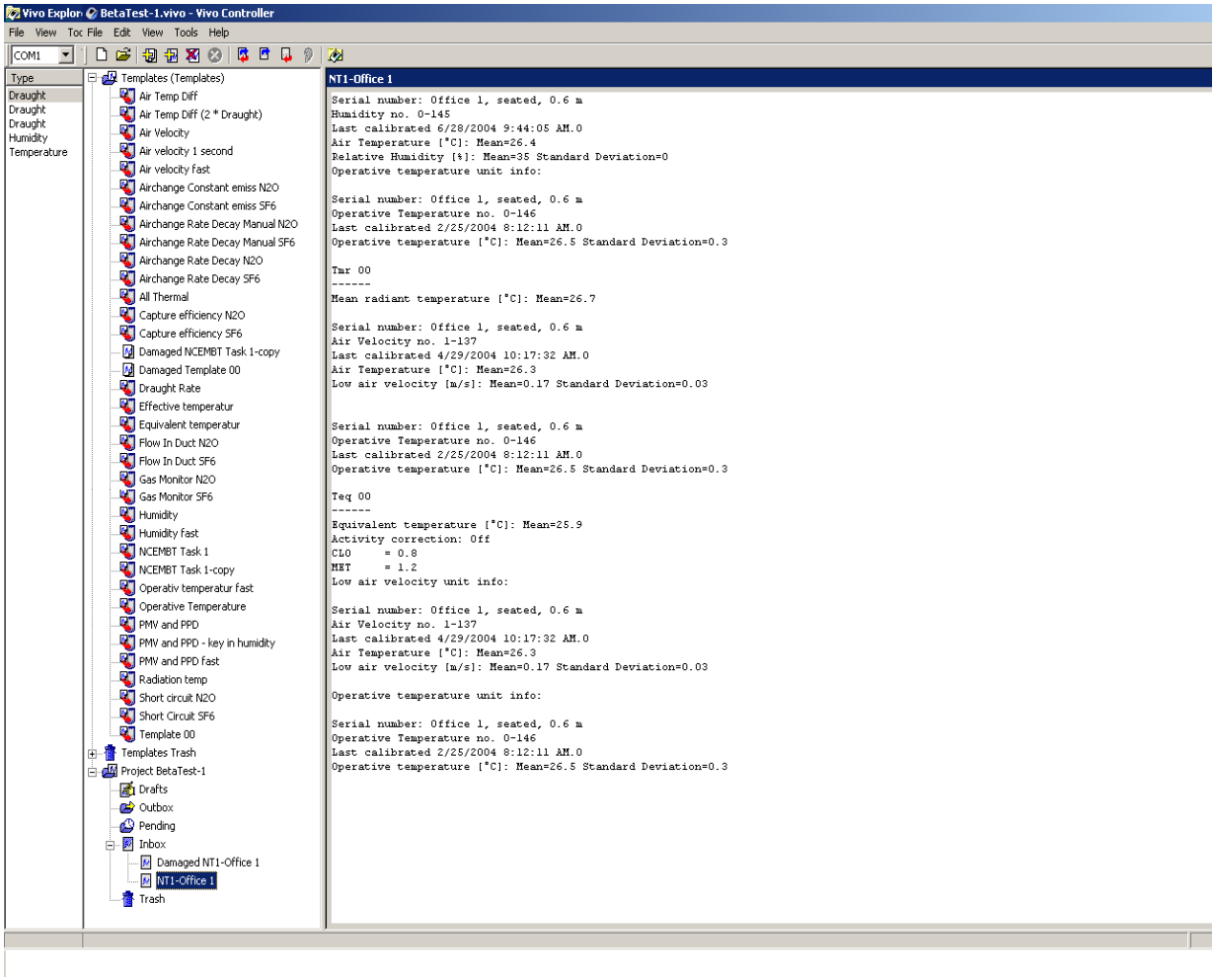


Figure E18. Screen Shot of VIVO Controller

3. Select File/Open/Project. (Ex.: project beta test, the project file is predefined.)
4. Modify the project by inputting information about the locations and heights of the sensors for sedentary or standing occupants.
5. Click the synchronize button. This helps in setting up all the required files and reads the required data from the sensors. Make sure that this process is done twice: once before the field study is conducted and once after the readings are all taken.
6. All data are shown initially in the INBOX. They are transferred to PENDING after the synchronization.
7. Finally the data are shown in the OUTBOX when the data acquisition is completed.
8. To display all graphics for all values, both measured and calculated:

9. Double-click the project name; or
10. Select Window/Cascade (Figure E19).

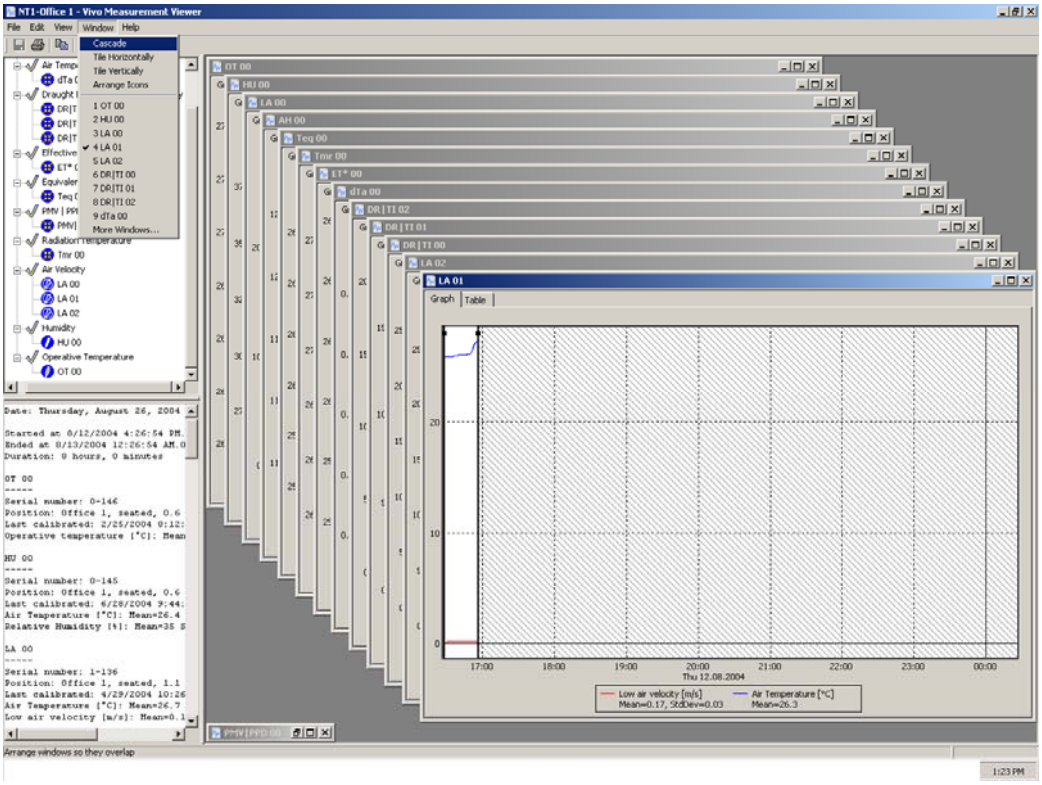


Figure E19. Screen View of VIVO Controller with Graphical Analysis

To save data:

11. Select File/Export.
12. Save as a text file. A default name will appear.
13. Select Export.

E2.4 Output From Sensors (Both Measured And Calculated)

The range and units of output data from the sensors are listed in Table E2. The output obtained from the sensors include:

1. Operative temperature
2. Relative Humidity
3. Air velocity
4. Draught rate
5. Equivalent temperature

6. PMV
7. PPD
8. Radiant temperature
9. Air temperature

Table E2. Listing of the expected range of data for each of the VIVO instruments

Type of senor	Measures	Expected Range	Units of Measurement
VIVO Draught	Low air velocity measuring unit	0.05–5	m/s
VIVO Temperature	Measures the operative temperature	5–40	˚C
VIVO Humidity	Measures the humidity of the air	0–100	%RH
VIVO Draught	Air Temperature	5–40	˚C
VIVO Draught	Turbulence Intensity		

E2.5 Assembly Of Super Battery And Stand

A super battery was purchased with an additional device for the regular battery. In a case of exigency, this provides an uninterrupted power supply. The battery is placed in the space provided at the bottom of the stand (Figure E20). The battery has a LED and a sensor which shows the adequacy of electric charge (Figure E21) so that the battery can be charged at regular intervals (8 hours) and be ready for the next data collection.

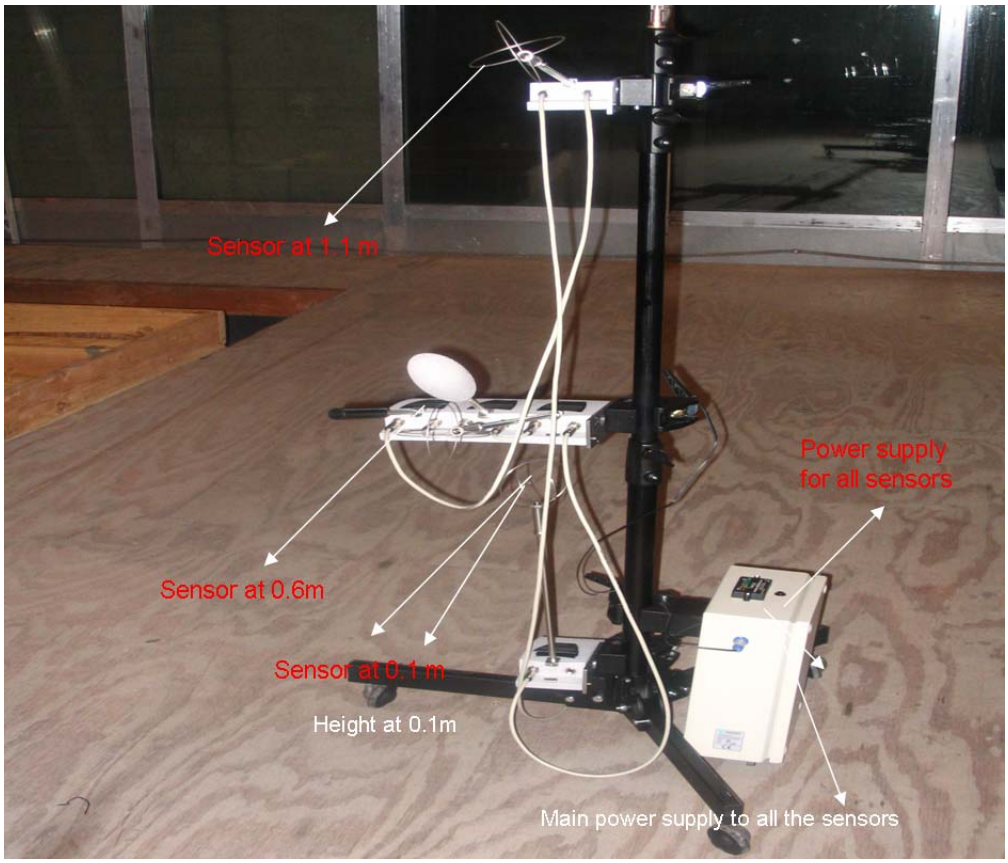


Figure E20. Complete Assembly of the Stationary Cart Stand with the Portable Battery

Figure E21. Battery Indicator

E3. Types Of Raw Variables Measured For Thermal Comfort

Several variables are measured using the VIVO instruments and several others are calculated by the sensors such as the different indices PMV and PPD to help in evaluating the overall thermal comfort in each of the different offices. Table E3 summarizes these variables knowing that the dry bulb temperature, relative humidity, and velocity (draft) were the measured variables while the remaining variables are all calculated.

Table E3. Parameter Names in Statistical Plots, their Meaning, and their Unit Values

Parameter Name in Table E2	Parameter Name in Statistical Plots	Parameter Meaning	Unit
Temperature	AirTempLA0_6m	Dry bulb air temperature at 0.6 m above the floor	°C
Operative Temperature	OpTemp	Operative Temperature measured at 0.6 m above the floor	°C
Relative Humidity	RelHumidity	Relative Humidity measured at 0.6 m above the floor	%
Humidity Ratio	HumidityRatio	Calculated Humidity Ratio based on temperature and relative humidity	kg water/ kg dry air
Velocity	LoAirVel0_6m	Air velocity at 0.6 m above the floor	m/s
Draft Rate (DR)	MaxDraftRate	Maximum draft rate among the draft rates in three heights, i.e. 0.1 m, 0.6 m and 1.1 m above the floor.	%
PMV	PredMeanvote	Predicted Mean Vote	
PPD	PredPctDissatis	Predicted Percentage of Dissatisfied	%
Vertical Air Temperature Difference	VertAirTempDiff	Vertical Air Temperature Difference between the air temperatures at 1.1 m and 0.1 m above the floor.	°C
Indoor to Outdoor CO_2 Differential Concentration		Indoor to Outdoor CO_2 Differential Concentration	ppm

Dry bulb air temperature data (Table E4) are obtained from the VIVO instruments at a height of 0.6m, which represents the location of torso of a person of average height sitting at a desk in an office setting.

Table E4. Description of Air Temperature and Operative Temperature Measurements (adapted from VIVO Documents available)

Criteria	Measurement Information	Citation
Parameter	Air temperature, operative temperature	
Symbol	t_a, t_o	
Unit	[°C]	
Definition	Air temperature is the temperature of the air around the human body. Operative temperature is the equivalent uniform temperature of an imaginary black enclosure in which an occupant would exchange the same amount of heat by radiation plus convection as in the actual non-uniform environment.	ISO 7726:1998 Ergonomics of the thermal environment-Instruments for Measuring Physical Quantities (http://www.iso.org)
Applies to	Global comfort (Measurement Procedure 1) Local comfort (Measurement Procedure 2).	
Equipment	Types of sensors: VIVO Temperature sensor each for ambient air temperature and operative temperature. Minimum required characteristics for measurement instruments: • Measuring range: 5°C to 40°C • Accuracy: ±0.5°C Response time should as short as possible. Precautions to be taken during use: Do not touch sensor with hands.	ISO 7726:1998
Measurement (Procedure 1)	Place sensor where the building occupants normally conduct daily activity or a limited zone of occupancy in poorly defined rooms. Measurement should be conducted in a number of positions. If the occupants' distribution is unknown, measurement should be conducted in the center of the room and 0.6 m from every surrounding wall or large window. Height: • In homogeneous environments: abdomen level. Height is 0.6 m (sitting) or 1.1 m (standing). • In heterogeneous environments: head, abdomen, ankle levels. Height is 1.1-0.6-0.1 m (sitting) or 1.7-1.1-0.1 m (standing). Suggested observation period is 480 minutes (8 hours) at a rate of 0.5-3 minutes.	ISO 7726:1998 ANSI/ASHRAE 55:2004 and Addendum 55a:1995
Measurement (Procedure 2)	Place sensor where the building occupants normally conduct daily activity or a limited zone of occupancy in poorly defined rooms. Measurement should be conducted in a number of positions. If the occupants' distribution is unknown, measurement should be conducted in the center of the room and 0.6 m from every surrounding wall or large window Height, head and ankle levels: • 1.1-0.1 m (sitting) and 1.7-0.1 m (standing) Suggested observation period is 480 minutes (8 hours) at a rate of 0.5-3 minutes.	ISO 7726:1998 ANSI/ASHRAE 55:2004 and Addendum 55a:1995

The actual relative humidity data used to deduce the statistical information (Table E5) are similarly obtained to that of the air data using the information from the VIVO instruments at 0.6m height. The

absolute humidity needed for determining where the average thermal conditions lie on the psychometric table is calculated from the relative humidity measured and the ambient air temperature.

Table E5. Description of Relative Humidity Measurements

Criteria	Measurement Information	Citation
Parameter	Relative humidity	
Symbol	RH	
Unit	[%]	
Definition	The relative humidity (RH) is the ratio between the partial pressure of water vapor (P) in humid air and the water vapor saturation pressure (P_{as}) at the same temperature and total pressure. Relative humidity is normally expressed as a percentage.	ISO 7726:1998
Applies to	Global comfort	
Equipment	Types of sensors: VIVO relative humidity sensor (figure 2). Required characteristics for measurement instruments: 0-100% RH Precautions to be taken during use: Sensor should not be touched with the hands.	ISO 7726:1998
Measurement	Place sensor where the building occupants normally conduct daily activity or a limited zone of occupancy in poorly defined rooms. Measurement should occur at one point in the room. Level Height, abdomen level: • 0.6 m (sitting) • 1.1 m (standing) Suggested observation period is 480 minutes (8 hours) at a rate of 3 minutes.	ISO 7726:1998 ANSI/ASHRAE 55:2004 and Addendum 55a:1995
Comfort limits	Absolute Humidity should not exceed 0.012 kg water/kg dry air.	

The mean air speed for statistical data manipulations (Table E6) is also obtained mainly from the VIVO sensor at a height of 0.6m. The Draft Rate (DR) is determined by sorting the maximum DR among three elevations at each station location: 0.1m, 0.6m, and 1.1m.

Table E6. Description of Air Velocity Measurements

Criteria	Measurement Information	Citation
Parameter	Air velocity	
Symbol	v_a	
Unit	[m/s]	
Definition	The air velocity is a quantity defined by its magnitude and direction. The quantity to be considered in the case of thermal environments is the speed of the air (i.e., the magnitude of the velocity vector of the flow at the measuring point considered).	ISO 7726:1998
Applies to	Global comfort (Procedure 1); Local comfort (Procedure 2).	
Equipment	Types of sensor: VIVO draught sensor Minimum required characteristics for measurement instruments: • measuring range: 0.05 – 5 m/s; • accuracy: ± (0.02 + 0.07 v_a) m/s. Response time should be the shortest possible. The following factors have to be considered for accurate velocity measurements: • the calibration of the instrument; • the response time of the sensor and the instrument; • the measuring period.	ISO 7726:1998
Measurement, Procedure 1	Place sensor where the building occupants normally conduct daily activity or a limited zone of occupancy in poorly defined rooms. Measurement should be conducted in a number of positions. If the occupants' distribution is unknown, measurement should be conducted in the center of the room and 0.6 m from every surrounding wall or large window. Height: • In homogeneous environments: abdomen level. Height is 0.6 m (sitting) or 1.1 m (standing). • In heterogeneous environments: head, abdomen, ankle levels. Height is 1.1-0.6-0.1 m (sitting) or 1.7-1.1-0.1 m (standing). Suggested observation period is 480 minutes (8 hours) at a rate of 3 minutes.	ISO 7726:1998 ANSI/ASHRAE 55:2004 and Addendum 55a:1995
Measurement, Procedure 2	Place sensor where the building occupants normally conduct daily activity or a limited zone of occupancy in poorly defined rooms. Measurement should be conducted in a number of positions. If the occupants' distribution is unknown, measurement should be conducted in the center of the room and 0.6 m from every surrounding wall or large window. Height, head and ankle levels: • 1.1-0.1 m (sitting) • 1.7-0.1 m (standing) Suggested observation period is 480 minutes (8 hours) at a rate of 3 minutes.	ISO 7726:1998 ANSI/ASHRAE 55:2004 and Addendum 55a:1995

E4. CALCULATED INDICES FOR THERMAL COMFORT

The PMV is calculated from an equation provided in Table E7. The effects of several variables and parameters are taken into account. In the present study, no measurements were made to characterize the M, W, l_{cl}, f_{cl}. While t_a was measured, h_c and p_a were calculated.

Table E7. Description of PMV Definition and Calculations

Criteria	Measurement Information	Reference
Parameter	Predicted Mean Vote	
Symbol	PMV	
Unit	None	
Definition	The PMV is an index that predicts the mean value of the votes of a large group of persons on the following 7-point thermal sensation scale: +3 hot +2 warm +1 slightly warm 0 neutral −1 slightly cold −2 cool −3 cold	ISO 7730:1994
Applies to	Global comfort	
Determination	The PMV index is derived for steady-state conditions, but can be applied with good approximation during minor fluctuations of one or more of the variables, provided that time-weighted averages are applied. Measure the following environmental parameters: • air temperature; • mean radiant temperature; • relative air velocity; • partial water vapour pressure, or relative humidity. In homogeneous environments these parameters should be measured at the abdomen level only. In heterogeneous environments they should be calculated as the average of the measured values at the head, abdomen and ankle levels. Estimate the following personal parameters: • activity (metabolic rate); • clothing (thermal resistance). Determine the PMV index either from the equation given in ISO 7730 (which may be solved by iteration) or using tables given in ISO 7730. Calculating equations are the following: $PMV = (0{,}303\, e^{-0{,}036\,M} + 0{,}028)\,\{(M - W) - 3{,}05 \times 10^{-3} \times [5\,733 - 6{,}99\,(M - W) - p_a] - 0{,}42 \times [(M - W) - 58{,}15] - 1{,}7 \times 10^{-5} M (5\,867 - p_a) - 0{,}001\,4 M (34 - t_a) - 3{,}96 \times 10^{-8} f_{cl} \times [(t_{cl} + 273)^4 - (\bar{t}_r + 273)^4] - f_{cl} h_c (t_{cl} - t_a)\}$ where:	

	$t_{cl} = 35{,}7 - 0{,}028\,(M - W) - I_{cl}\{3{,}96\times10^{-8} f_{cl} \times [(t_{cl}+273)^4 - (\bar{t}_r+273)^4] + f_{cl} h_c (t_{cl} - t_a)\}$ $h_c = \begin{cases} 2{,}38\,(t_{cl}-t_a)^{0{,}25} \text{ per } 2{,}38\,(t_{cl}-t_a)^{0{,}25} > 12{,}1\sqrt{v_{ar}} \\ 12{,}1\sqrt{v_{ar}} \text{ per } 2{,}38\,(t_{cl}-t_a)^{0{,}25} < 12{,}1\sqrt{v_{ar}} \end{cases}$ $f_{cl} = \begin{cases} 1{,}00 + 1{,}290\,I_{cl} \text{ per } I_{cl} \le 0{,}078\ m^2 \cdot °C/W \\ 1{,}05 + 0{,}645\,I_{cl} \text{ per } I_{cl} > 0{,}078\ m^2 \cdot °C/W \end{cases}$ M is the metabolic rate [W/m²]; W is the external work [W/m²]; I_{cl} is the thermal resistance of clothing [m²°C/W]; f_{cl} is the ratio of "man's surface while clothed" to "man's surface while nude"; t_a is the air temperature [°C]; p_a is the partial water vapour pressure [Pa]; h_c is the convective heat transfer coefficient [W/m²°C]	
Calculation	The PMV index can be determined when: • the activity (metabolic rate) and the clothing (thermal resistance) are estimated; • air temperature, mean radiant temperature, relative air velocity, and partial water vapor pressure are measured.	ASHRAE 55-2004

The mean vote (MV) represents the mean value of the votes of the questionnaire participants on the seven-point thermal sensation scale. Predicted Mean Vote (PMV) is an index that predicts the mean value of the votes of a large group of persons on the seven point thermal sensation scale (ASHRAE, 2004). PMV can be calculated from the known air temperature, mean radiant temperature, humidity, mean air speed, metabolic rate, and clothing insulation (ASHRAE, 2004).

The ASHRAE seven-point thermal sensation scale is defined as follows:

+3 hot
+2 warm
+1 slightly warm
0 neutral
–1 slightly cool
–2 cool
–3 cold

In the perception questionnaire, however, a five point thermal sensation scale was used:

1 very cool
2 somewhat or slightly cool
3 neither cool nor warm
4 somewhat or slightly warm
5 very warm

To calculate MV, the five point scale is converted to a seven point scale by using the following equation:

$$MV = \frac{3X - 9}{2} \quad (1)$$

Where, X = the mean value of votes based on the five point thermal sensation scale. PMV is then compared to MV.

The predicted percentage of dissatisfied occupants (PPD) is an index that establishes a quantitative prediction of the percentage of thermally dissatisfied people determined from PMV (ASHRAE 55- 2004). The following equation is used to calculate PPD:

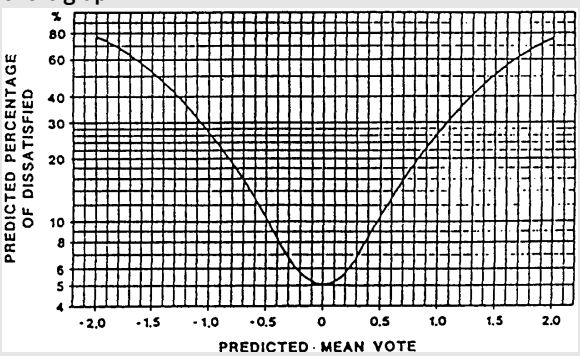
$$PPD = 100 - 95\exp\left(-0.03353PMV^4 - 0.2179PMV^2\right) \quad (2)$$

The percent dissatisfied (PD) represents the percentage of occupants that are dissatisfied due to discomfort, including vertical air temperature difference (either cool in feet or warm on head), humid or dry air (either very humid or very dry), and stuffy environment (never or occasionally feel fresh). To verify the correctness of the PPD value (Table E8), the PD is calculated by the following equation:

$$PD = 100 - 95\exp\left(-0.03353MV^4 - 0.2179MV^2\right) \quad (3)$$

MV is the scaling factor that links survey responses to ASHRAE standards.

Table E8. Description of PPD Calculations

Criteria	Measurement Information	Reference
Parameter	Predicted Percentage of Dissatisfied	
Symbol	PPD	
Unit	[%]	
Definition	The PPD is an index that predicts the number of thermally dissatisfied persons among a large group of people.	ASHRAE 55-2004
Applies to	Global comfort	
Determination	PPD can be determined by the equation: or the graph: 	ASHRAE 55-2004

The vertical air temperature difference is usually defined as the difference of the air temperature between the head location (for a seated person 1.1m) and the feet (i.e. 0.1m). This has been suggested also as a possible contributor to thermal discomfort for occupants. Although its value is not included in any of the calculated indices i.e. PPD its effect on thermal comfort is being sensed from the questionnaire and also in the section involving the hypotheses to be tested from the engineering data and the questionnaire presented later on.

Draft rate (DR) is a function of local air temperature, mean air speed and turbulence intensity. It represents the predicted percentage of people dissatisfied due to annoyance from drafts. The model used to calculate DR (DR-ASHRAE) is based on known air temperature, mean air speed, and turbulence intensity (ASHRAE, 2004). Based on the occupant perception questionnaire results, the percentage of

people dissatisfied due to draft (DR-Survey), either very drafty or very stagnant, can be calculated and compared to DR-ASHRAE (ASHRAE 2004). The DR-ASHRAE may or may not agree with the DR-Survey because the DR-ASHRAE model was developed from laboratory tests and survey results, but the DR-Survey is derived from field measurements. The equation governing DR is (ASHRAE 55-2004):

$$DR = ([34 - t_a] * [v - 0.05]^{0.62}) * (0.37 * v * Tu + 3.14) \quad (4)$$

Where DR is the predicted percentage of people dissatisfied due to draft; t_a is the local air temperature measured in °C; v is the local mean air speed measured in m/s; and Tu is the local turbulence intensity, %. The total number of estimated measured and calculated entries for the database is summarized in Table E9.

Table E9. Summary of the Number of Measurements (#) by Category for Raw Data and the Calculated Indices for the IEQ Instruments for Database Allocation Space

Height	Sensors	Raw Data		Calculated Indices		Number of Bins
		Category(s)	#	Category(s)	#	
0.1m	VIVO Draught	Air Temperature Air Velocity	3	PD/DR	1	4
0.6m for sedentary occupants/ 1.1m for standing occupants	VIVO Draught	Air Temperature Air Velocity	3	PD/DR	1	4
	VIVO Operative Temperature	Operative Temperature	1	PMV PPD ET* Radiant Temperature EHT for car measurement	5	6
	VIVO Humidity	Relative Humidity	2	Absolute Humidity	1	2
1.1m for sedentary occupants 1.7m for standing occupants	VIVO Draught	Air Temperature Air Velocity	3	PD/DR Vertical Air Temperature Difference	2	5
Total	-	-	12	-	10	21

APPENDIX F: CO_2 SENSORS

F1. DESCRIPTION OF SENSORS

Three different instruments were used to measure CO_2 concentrations. A single Bacharach comfort check sensor (Figure F1) measured outdoor CO_2 concentrations for eight hours every day of data collection.

Figure F1. Bacharach Comfort Check Sensor

Six Hobo sensors (Figure F2) were used to measure indoor CO_2 concentrations in six locations continuously during data collection.

Figure F2. HOBO CO2 Sensor
(http://www.onsetcomp.com/Products/Product_Pages/HOBO_H08/H08_family_data_loggers.html#Anchor-HOBO-23240#Anchor-HOBO-23240).

One IAQRAE sensor (Figure F3) was used to measure indoor CO_2 concentrations for a short time period (less than 10 minutes) in six locations to compare readings with those of the Hobo. Another IAQRAE was used to measure outside CO_2 concentrations continuously.

Figure F3. IAQRAE Sensor

F2. STANDARD OPERATING PROCEDURES FOR THE USE OF THE BACHARACH

The Standard Operating Procedure for the use of BACHARACH for the measurement of outside CO_2 was developed from the manufacturer's user manual.

TO LAUNCH THE BACHARACH:

1. Ensure temp probe is locked in place.
2. Push and hold orange button to turn on. This makes a loud beep, so try to muffle the monitor with your hands. It takes a couple of minutes to warm up.
3. Plug the IrDA interface cable into the computer.
4. Open the Plus-Com/Bacharach program.
5. The top left data box should read "Not active" with the LINK button right next to it.
6. Line up the CO2 monitor and the IrDA cable. (The sensor sight should be about 1 inch apart.)
7. Select "LINK".
8. Check the battery status on the bottom left.
9. Check the memory status on the bottom right.
10. Check the time to make sure it matches the computer.
11. Select configure monitor from top menu. A Log frequency menu will appear. Select the Log time that you want. (We have been logging every 5 MINUTES)
12. Hit Program.
13. Hit OK.

DO THE FOLLOWING STEPS OUTSIDE AS THE MONITOR MAKES A LOUD BEEPING SOUND WHEN YOU TURN IT ON!!!

TO BEGIN DATALOGGING:

- On the CO2 Monitor PRESS AND HOLD F1 until the blinking "Θ" appears on the right side of the menu screen.
- You are now Datalogging.

TO SAVE THE DATA:

- OUTSIDE of the building (because of loud beep) PRESS AND HOLD F1 for 3 SECONDS. The "Θ" will disappear. This stores the data.
- DO NOT SHUT THE MONITOR OFF.
    1. Attach the cord and line up the IrDA sensor with the CO2 monitor sensor.
    2. Select Link.
    3. Select Download.
    4. Select Save.
    5. At this point you have the option of where you like to save it.
    6. Once you have saved the data, you must erase it from the monitor. To do this select CLEAR. It will look like the data are still there but when you shut the monitor down and power up again it will be gone.

THIS MONITOR NEEDS TO BE CHARGED EVERY NIGHT.

F3. STANDARD OPERATING PROCEDURE FOR THE USE OF HOBOS

The Standard Operating Procedure for the use of HOBOS for the measurement of inside CO_2 was developed from the manufacturer's user manual.

TO LAUNCH HOBO DATALOGGERS:

1. Connect GREY cord to back of computer and to the HOBO.
2. Turn on CO2 Monitor by pressing blue button.
3. Open BOXCAR 3.7 (Saved on Desktop).
4. Select LOGGER.
5. Select LAUNCH. (Launch Screen appears.)
6. Check battery status. (NOTE: This is the battery level for the HOBO ONLY).
7. Change Description ID to the appropriate MINOR ID#.
8. Change Log Interval to 1 Minute. (It should already be set at one minute, but check just in case.)
9. DESELECT "Wrap around when full".
10. Select Start------. A warning screen will appear "UNPLUG THE LOGGER BEFORE SELECTING OK".

TO DOWNLOAD DATA:

1. Connect cord to computer and HOBO.
2. Open BOXCAR/HOBO Program.
3. Select LOGGER.
4. Select HOBO SHUTTLE READOUT.
5. UNPLUG LOGGER BEFORE SELECTING OK.
6. A "Save As" Screen will appear.
7. HIT CANCEL.
8. Select FILE.
9. Select EXPORT.
10. Select MICROSOFT EXCEL.
11. Under Data Setting select the following Channels:
12. Temperature in Celsius
13. Humidity
14. Dew Point in Celsius
15. THE LAST VOLTAGE CHANNEL (Channel 4). It is VERY important that you select the LAST voltage channel. This is our CO_2 Data.
16. Select EXPORT. The EXPORT screen will appear.
17. Under File Name Change this to the MINOR ID #.txt. ENSURE THAT IT IS SAVING AS A "TXT" FILE.
18. Select the appropriate folder for saving this file.

F4. STANDARD OPERATING PROCEDURE FOR THE USE OF IAQRAE

The Standard Operating Procedure for the use of IAQRAE for the measurement of CO_2 was developed from the manufacturer's user manual.

To Turn ON:

1. Press **[MODE]**. The unit will beep once and screen will display program information.
2. The monitor will display the sensor name after the monitor is turned on.
3. The IAQRAE begins the instantaneous reading of the actual gas concentrations.
4. The Instantaneous Reading function alternately displays the instantaneous reading and the sensor name.
5. The instantaneous reading is the actual gas concentration in parts per million (PPM) for CO_2 or VOC gases; percent relative humidity (%RH) for relative humidity; and degrees Celsius (°C) or degrees Fahrenheit (°F) for temperature.
6. The monitor displays the number of minutes that the instrument has been running. To stop instantaneous readings turn off the IAQRAE.

You may enter an eight-character site identification which will be included in the datalog report. To change the site identification:

1. At the "**Change Site ID**" screen:
2. Press **[Y/+]** and the display will have the current site ID: "Site ID = xxxxxxxx".
3. **Press [MODE]** to move the cursor to the left most digit.
4. Press **[Y/+]** or **[N/-]** to cycle through all 26 letters and 10 numerals. Hold down **[Y/+]** or **[N/-]** for rapid scrolling.
5. Press **[MODE]** to advance to the next digit on the right.
6. Repeat until all 8 digits have been entered.
7. Press [**MODE]** to move the cursor to "**SAVE?**"
8. Press **[Y/+]** to accept the new site identification and exit the submenu.
9. Press **[N/-]** to discard the changes and advance to the next submenu.
10. To Turn OFF:
11. Press and hold **[MODE]** for 5 seconds. The monitor will beep once every second during the power-down sequence
12. The screen will flash "Off" and then go blank

NOTE: A fully charged battery pack should show 7.7 volts or higher. When the battery charge falls below 6.6 volts, a flashing "Bat" will appear as a warning message. This means, there will be approximately 20-30 minutes of operating time remaining before the monitor automatically turns off as the battery voltage falls below 6.4V.

Calibration of the IAQRAE

The IAQRAE uses a two-point calibration process with "zero" or "low Conc. Gas" as the first point of reference and a "standard higher conc. Gas" as the second point of reference. A standard reference gas (span gas) contains a known concentration of a given gas. Zero calibration should be done before performing span calibration of sensors.

NOTE: Fresh ambient air cannot be used to zero the VOC, CO_2 or RH sensors because of the background presence of these components.

1. The PID sensor zero should be performed using a cylinder of dry zero-VC air or nitrogen.
2. When the **"Calibrate Monitor?"** screen appears. Press **[Y/+]** to start calibration
3. If a bottle of zero air is being used, attach the calibration adapter to the gas inlet port. Connect the other end of the tube to the bottle of zero air.
4. NOTE: If a bottle of zero air is not available, place the monitor in a contaminant-free area outdoors or attach a single use zeroing tube.
5. Press **[Y/+]** to start zero air calibration.
6. The display will show "calibration is progress" followed by the name and reading of the CO and VOC sensors, and the messages "zeroed."
7. The display should show a reading "0.0" or a very small number for both sensors.

8. After a two-second pause, the display will show "**Zero-Cal Done**!" and flash sensor readings for about ten seconds before moving to the next submenu.
9. The next display will read "**Multiple Sensor Calibration**?".
10. Press **[N/-]** to move onto the next submenu, "ingle Sensor Calibration".
11. At the "Single Sensor Calibration" screen, press [Y/+].
12. The display shows the sensors installed in the monitor with the cursor blinking on "**GO?**".
13. Press **[Y/+]** to select a sensor and start the calibration or press **[MODE**] to move to the next sensor location.
14. Turn gas flow off. Disconnect calibration tube from monitor.

APPENDIX G: VOLATILE ORGANIC COMPOUNDS MEASUREMENTS

G1. DESCRIPTION OF SENSOR

The IAQARE is a highly versatile indoor air quality measurement device that offers upto fiie plug-in sensors. It continually measures VOCs at 0 to 500 ppm with 0.01 ppm (10 ppb) resolution continuously up to 24 hours from built-in lithium-ion battery. It can datalog up to 20,000 data points and has a built-in motorized sample-draw pump. It combines a photoionization detector for total VOC measurement with traditional indoor quality measurement parameters such as temperature, relative humidity, carbon dioxide, and an additional substance-specific toxic gas sensor all in one portable instrument (see Appendix F; Figure F1).

G2. STANDARD OPERATING PROCEDURE

The following protocol was used to measure the total VOC concentration.

G2.1 To Launch IAQRAE

1. Turn IAQRAE on – Push **MODE** button
2. Plug interface cable into the right side of the IAQRAE and the back of the computer
3. Push MODE button 7 times, until **"Communicate with PC?"** appears on IAQRAE screen
4. Select **"Y/+"** (This means Yes)
5. IAQRAE display should say, **"READY……."**
6. Open ProRAE Suite program
7. Select **COMMUNICATION** from the menu on top
8. Select Receive Configuration
9. Select OK when warning about connecting the instrument to serial port……..
10. The computer screen should say "Contacting instrument"
11. You will then get a screen that is titled Config 1
12. On the top menu behind the Config 1 page, select **EDIT**
13. Then select **CONFIGURATION**
14. Under the General tab do the following:
15. Change the Site ID
16. Ensure the Datalog Interval is 30 seconds
17. Clock from PC---Select YES
18. Under Datalog Mode---select **SCHEDULED START/STOP**
19. Set the Start/Stop time for 10 minutes (09:02-09:13; use the 24 hour [military] time). It will stop sampling at the beginning of the 10th minute so you have to set it for 11 minutes.
20. Select OK

21. The Config page should show the changes
22. Select Communication
23. Select SEND Configuration
24. You will get a warning page----Just select OK
25. At this point the computer monitor should read “Sending data packets to instrument…….”
26. You will then get a success box. IF you do not get this box you will need to
27. RE-SEND the configuration (start over at step 16).
28. Once this is complete:
29. Disconnect the IAQRAE
30. Press **MODE, ONCE** on the IAQRAE to return it to normal sampling mode
31. Move the IAQRAE to the sampling location
32. The IAQRAE will automatically turn on and off
33. When the IAQRAE begins datalogging, a small “L” will blink in the center of the monitor display.

TIPS:

If you get a “PUMP” warning blinking in the center of the display on the IAQRAE, turn the it off (hold the MODE button for 5 seconds as it powers down) And turn it back on.

If that does not work, then you may need to change the filter on the pump. There are extra filters in the case.

G2.2 To Save Data

The IAQRAE has finished datalogging when the “L” is no longer blinking on the display

1. Follow Steps 2-6 Under “TO LAUNCH IAQRAE”
2. Select COMMUNICATION
3. Select Receive Data
4. A screen will appear with the datalog
5. Your data will be that LAST EVENT OR HIGHEST NUMBERED EVENT under text mode of the Event Column(Left Side of Screen)
6. Select Option, then Export data
7. The Save as Box will appear. Select the location where you want the file save to. File name should be the Minor ID location. File type is tab delimited text file.
8. Go to folder on the computer and open the file you just saved
9. TO OPEN THE FILE YOU MUST DO THE FOLLOWING
10. RIGHT Click on the file
11. Select OPEN WITH
12. Select EXCEL

13. The Date and Time will be ########
14. Highlight the column
15. RIGHT Click and Select Format Cell
16. Select Date
17. Select “3/14/01 13:30” Format
18. Resave File

APPENDIX H: AIRBORNE AND SURFACE-ASSOCIATED MOLD PROTOCOLS

H1. General Description of Sampling Logistics

Air samples for culturable fungi and total fungal spores were collected using commercially available instrumentation positioned on a collapsible cart for ease of transport within the buildings and a consistent height from the floor. The height of the cart was fixed at 1.0 m. Settled dust was collected using vacuum sampling. Air and surface samples were collected in the morning at each of the six indoor locations. Outdoor air samples were collected prior to the first indoor sample and a second outdoor sample was collected after the 6th indoor sample.

H2. Culturable Air Sampling Protocol

Air samples for culturable fungi were collected using the Andersen single-stage impactor sampler (Graseby Andersen, Atlanta, GA) operated at 28.3 liter/min. flow rate for 2 min. (0.057 m^3 of air per sample). Samples were collected onto malt extract agar (Difco Laboratories, Detroit, Mich.) amended with chloramphenicol (MEAC). The sampler was decontaminated with an ethanol wipe between each sample location. All agar plates were taped, bagged, and transported to the laboratory consultant (Natural Link Mold Laboratory, sparks, NV) the day of collection via commercial overnight carrier. Culturable fungi on the Andersen samples were identified using macroscopic and microscopic morphology. The number of colony forming units (CFU) of fungi collected with the Andersen sampler were recorded as CFU/plate. The concentration of culturable CFU per cubic meter of air (CFU/m3) were determined using the airflow rate and sampling time. Positive hole correction was used as needed according to manufacturer's protocol. The lower limit of detection for air sampling with the Andersen sampling method as described above was 18 CFU/m3. The resulting colonies were identified to the genus level, although Aspergillus and Penicillium were identified to the species level.

H3. Non-Culturable Air Sampling Protocol

Samples for airborne fungal spores were collected using the Burkard personal impactor sampler (Burkard Manufacturing Co., Ltd., Rickmansworth Hertfordshire, England) operated at the fixed flow rate of 10 liters/min. Samples were collected for 2-5 minutes (0.02-0.05 m3 of air). The sampler was decontaminated with an ethanol wipe between each sample location. Burkard slides were transported to the UNLV microbiology laboratory for analysis where they were stained and viewed with light microscopy for the presence of recognizable fungal spores. The number of spores per slide were recorded and the concentration of spores per cubic meter of air (spores/m3) determined using the airflow rate and the sampling time. The lower limit of detection for air sampling with the Burkard sampling method described above varies was 20-50 spores/m3 depending on the length of sampling collection. This methodology permits identification of recognizable spores to the genus level. Additional non-fungal structures (i.e., skin cells, particulate) were recorded semi-quantitatively.

H4. Vacuum Sampling Protocol

Vacuum sampling using an individual field filter cassette attached to a vacuum pump was used to sample porous or hard surfaces for settled particulate. Sampling was conducted on flooring at each indoor location. A fixed area was not sampled because the data were reported as the number of CFU per gram of sample processed. Each cassette was labeled and placed in a plastic bag and transported to the consultant laboratory (Natural Link Mold Laboratory). The material collected in the vacuum samples were weighed,

processed and spread plated onto a series of growth media. The plates were incubated and the resulting fungal colonies identified to the genus level, although Aspergillus and Penicillium were identified to the species level. The fungal colonies cultured from the vacuum samples were identified by microscopic and macroscopic morphology, and recorded as the number of CFU/plate. Enumeration of the concentration of organisms per gram of material sampled was calculated using the dilution factor and appropriate sample information. Storage of samples for up to 25 days at refrigeration or room temperature has been shown not to affect the results (Macher, 2001a and b), but the samples were shipped at the end of each day's collection to avoid degradation of the samples.

APPENDIX I: SOUND PROTOCOLS

I1. INSTRUMENT SELECTION AND DESCRIPTION

Meters were chosen based on the investigators' personal knowledge of sound testing and knowledge gained from the literature review on what data should be captured. Svantek sound level meters were chosen for measurement of sound in the building interior. Six Svantek 948 meters that can record up to four microphones each and the one backup Svantek 947 that can record one microphone were determined to be suitable for the measurements desired (Figure I1).

The meters recorded one-third octave band and three overall sound levels for each interval specified. For Task 1, two microphones per meter were used. One-third octave band levels from 0.8 Hz to 20K Hz were recorded, but based on microphone sensitivity, only the one-third octave levels from 20 Hz to 10K Hz were faithfully captured. The three overall levels were the weighted sound levels of dBA, dBC, and Linear. The overall levels, full octave band levels, and all the sound descriptors can be derived from the one-third octave band levels. The meters were set up for autonomous automatic startup and shutdown for a specific period each day of testing. Power from a local electrical receptacle was used for nearly all testing, but meter could also record for approximately 24 hours, slightly over two days of Task 1 testing, on internal batteries.

Figure I1. Svantek SVAN 948 and SVAN 947 Sound Level Meters

To support the microphones and sound level meters, various length BNC cables, microphone stands, and microphone clips were used. One microphone could be placed up to 100 feet from the meter while the other was on a 10-foot cable. The stands allow placing the microphone anywhere on the floor space. The microphone clips made it possible to place the microphone near any object, shelf, or piece of furniture without occupying floor space. The clips were also much smaller and lighter than the stands.

The Svantek meters store all measurements in their on-board, non-volatile memory. This has the advantage of storing multiple measurements and retaining measurement data even if the meter is

shutdown or loses power. The data can be easily downloaded in file format to any PC using Svantek software.

I2. FIELD-TESTING PROCEDURES

Beta testing was performed with the meters to measure the sound environment of several rooms on the UNLV campus as an example of the types of measurements that would be collected during Task 1. From this, a standard operating procedure (SOP) for Task 1 was developed to compensate for any difficulties that may be encountered during sampling of the buildings.

The SOP included safety instructions, equipment lists, field testing departure checklist, packing and shipping procedures, on-site setup, and office testing. It was designed to be a stand-alone document for field team members who have some familiarity with sound testing and instruments knowledge of the instruments. The manufacturer-supplied user guides are used for in-depth knowledge of the equipment and for troubleshooting equipment problems.

Sound measurements were made at two locations in each of six zones in the tested building. The intent was to have one microphone in a typical location in an area of normal activity and the second microphone in a location away from normal activities (where sound levels may be typical of the background sound in study area). In practice, this was not practical because those two locations, if they existed, were often too far apart to safely run connecting microphone cables safely. In some cases there was no location away from normal activity that was accessible.

Therefore, for all cases the microphones were positioned such that one was co-located with the monitoring stand. The other was positioned as far away as possible, consistent with safety and not interfering with normal work at the location. In nearly all cases, the close microphone was located in a cubicle with the comfort station. The second microphone could be at a different area of the same cubicle, in the neighboring cubicle, or in the hallway near that cubicle. This arrangement is shown in Figure I2. In a few cases the first microphone and the monitoring stand were in a hallway or common area. That alternate arrangement is shown in Figure I3. In those cases, the second microphone was located in the same hallway or common area but 10 to 50 feet away from the first microphone.

Each location measured for 10 hours each day, enough time to capture continuous sound levels of the general background sound with no building occupants present and continuous sound levels over a typical workday. Continuous 1 to 10-second time-averaged energy equivalent sound levels (Leq) for all one-third octave bands between 0.8 Hz and 20 kHz were measured, time stamped, and stored in the SLMs. A Leq value is defined as the sound level for a constant sound over a specific time period that has the same sound energy as the actual sound measured over the same period. Following the measurements, data were downloaded to a computer for post processing.

Figure I2. Typical microphone locations (left, the first microphone is in the cubicle with the comfort station; right, the second microphone is in the hallway next to the cubicle.

Figure I3. Alternate microphone locations (both microphones are in a common use hallway between cubicles).

I3. Sound Related Portion Of The Data Reduction And Analysis

Although all the necessary data were contained in the data files, the format is not suitable for immediate entry into the project database. Therefore, a data conversion software program was created for reformatting the data into a database entry format. The program is interactive, with a graphical interface that prompts the user to supply the necessary information to categorize the data. This ensured that data collected were always properly identified and presented in a consistent, useful format. An illustration of the user interface is shown in Figure I4. The format of the data file output of the program consisted of header lines where identifying information was written so that data could always be identified with the test. The columns of data began with the time of the recording, the three overall levels, the full octave band levels, and then the one-third octave band levels. Figure I4 only illustrates the time, overall levels, and a few of the full octave band levels for several measurements of a test. The full octave band data were calculated from the one-third octave band data and were entered into the data file for easy use in determining some of the derived acoustic parameters. The one-third octave band levels from 12.5 Hz to 10000 Hz were transferred to the database format file. The interface displayed some important details of

the data file immediately after converting the data. The example file shown in Figure I5 shows the date the data were taken, the starting time, the sample interval and the number of measurements in the file. A typical data file for Task 1 testing will have approximately 3600 measurements (10 hours). The size and format of the converted data files are formatted for entry and storage as permanent records into the database used for statistical analysis.

Figure I4. User Interface for Conversion of Svantek Files to Database Entry Files.

Data recording date: 30AUG01
Data recording start time: 13:13:44
Building address:
4505 S Maryland Pky
Las Vegas NV
Building floor: first
Location on floor: VAST laboratory

Time	SPL_A	SPL_C	SPL_lin	1/1 16 Hz	1/1 31.5 Hz	1/1 63 Hz
13:13:44	35.1	39.1	40.9	33.1	34.6	33.8
13:13:54	35.1	39	40.8	32.9	34.6	33.3
13:14:04	35.1	39	41.1	34.3	34.6	33.3
13:14:14	35.1	38.9	40.8	33.2	34.5	32.9
13:14:24	35.1	38.9	40.8	33.8	34	33.2
13:14:34	35.1	38.9	40.6	32.2	34.5	33
13:14:44	35.1	38.9	40.8	33.3	34.2	33.2
13:14:54	35.1	38.8	40.6	32.9	33.8	32.8
13:15:04	35.1	39	40.9	33.4	34.5	33.4
13:15:14	35.1	39	40.9	33.8	34.3	33.5
13:15:24	35.1	39	40.8	33.1	34.2	33.6
13:15:34	35.1	38.8	40.6	33.2	34.1	33
13:15:44	35.1	39	40.8	32.8	34.5	33.4

Figure I5. Representation of a Spreadsheet Data File Created for Svantek Database Input.

The following sound descriptors were derived from the measured sound data:

- RC values (RC – Room Criteria): Room Criteria (Mark II method) is the ASHRAE recommended method to determine the acceptability of background HVAC related sound in unoccupied indoor areas (Reynolds 2003). RC curves have the advantages of assessing the speech communication or masking properties of the noise, identifying the quality or character of the background noise due to both its spectrum shape and level, and assessing the possibility of perceptible vibration in buildings by using data in the 16 to 31.5 Hz frequency range (ASHRAE 1995).
- NC values (NC – Noise Criteria): Noise criteria curves were originally developed to specify just acceptable air conditioning noise but have been extended to more general purposes. Experience has indicated that correlation is poor between the calculated NC levels and an individual's subjective response to the corresponding background sound (Reynolds 2003).
- NCB values (NCB – Balanced Noise Criterion): Balanced Noise Criteria is similar to NC but with adjustments made to the shape of the curves to better correspond to an individual's subjective response to the corresponding background sound (Reynolds 2003).
- dBA values (dBA – A-weighted sound level): The A-weighted sound criteria was designed to approximate the response of the human ear at low sound levels. The characteristic of the criteria is to adjust the linear (raw) sound level values in relation to the ears sensitivity. Liner levels at frequencies below 1000 Hz and above 5000 Hz are progressively adjusted down while frequencies between 1000 and 5000 Hz are adjusted slightly up with 2500 Hz the highest with a 1.3 dB addition (Beis and Hansen 1997). A-weighted is probably the most common, well-known sound level measure.
- SIL values (SIL – Speech Interference Level): Speech Interference Level values are averages of sound levels in 500, 1000, 2000, and 4,000 Hz octave bands. SIL emphasizes the frequency range sensitivity that is most critical for understanding human speech (Reynolds 2003).
- PSIL values (PSIL – Preferred Speech Interference Level): Preferred Speech Interference Level values are averages of sound levels in 500, 1000, 2000, Hz octave bands. PSIL is the same as SIL, without the 4000 Hz contribution. PSIL is used to set the level of the RC curves at 1000 Hz (ASHRAE 1995).
- dBC – dBA values (dBA – A-weighted sound level, dBC – C-weighted sound level): The C-weighted sound criteria was designed to approximate the response of the human ear at sound levels of 85 dB. Because at 85 dB, down to 125 Hz the human ear has a much flatter frequency response than at low sound levels (A-weighting criteria), subtracting dBC from dBA results in highlighting the low frequency content of the sound (Beis and Hansen 1997).
- dBLin – dBA values (dBA – A-weighted sound level, dBLin – Linear weighted sound level): This also results in highlighting the low frequency content of the sound but has higher emphasis on very low frequencies (below 125 Hz) than the dBC-dBA values (Beis and Hansen 1997).

Values associated with the above sound descriptors, if not directly recorded, were calculated from the recorded data. All measures were calculated for each 10-second interval over a continuous time intervals that comprise a typical workday. Statistical analyses were then conducted on the descriptors in the form of a cumulative probability function. From that function, it was straightforward to determine the following levels that define the percent of the time that the sound exceeds that level (Reynolds 2003):

- L01– the level of sound that is exceeded 1% of the time;
- L05 – the level of sound that is exceeded 5% of the time (normally representative of average of peak sound levels);

- L10 – the level of sound that is exceeded 10% of the time;
- L20 – the level of sound that is exceeded 20% of the time;
- L33 – the level of sound that is exceeded 33% of the time (normally representative of overall average sound level);
- L50 – the level of sound that is exceeded 50% of the time;
- L67 – the level of sound that is exceeded 67% of the time;
- L90 – the level of sound that is exceeded 90% of the time (normally representative of general background sound levels);
- L95 – the level of sound that is exceeded 95% of the time.

Other levels such as L15 or L25 are also available for use. To account for possible occupant accommodation to certain levels, differences in the levels were also used to look for correlation with occupant perception of their sound environment. For example, L05 - L90 gives the incremental difference in sound level from background to peak levels.

I4. Standard Operating Procedure For Sound Measurement Instruments

The purpose of these procedures is to detail safe effective procedures for the required sound testing, protest the equipment from damage and misuse, reduce the uncertainty and workload of the testing team and to help ensure consistent successful measurements. These procedures are designed to cover all anticipated test situations. However, it is likely that unanticipated situations will occur and require deviation from these procedures. The test team must use good judgment at all times when following or deviating from these procedures, keeping in mind the goals for the testing and motivation for these procedures.

I4.1 Safety Instructions

To avoid personal injury, equipment damage and lost data, be familiar with all instructions before installation and use of the sound measurement equipment. Standard precautions include:

Carefully connect microphones and cables, avoiding bending connector pins

Pay attention when disconnecting the microphones from the preamp, the diaphragm cover can be inadvertently removed from the microphone body instead of the microphone from the preamp. Never touch the diaphragm of the microphone.

Consider trip hazards and the possibility of knocking over the microphone or sound level meter when cables are run from the meter to the microphones and when stands are placed on the floor. Tape cables as necessary to minimize hazards.

Connecting microphones or cables while meter power is on may cause permanent damage to the microphones or the sound level meters. Always turn off power before a cable is connected or disconnected.

None of the sound measurement equipment is waterproof and has only mild shock resistance. The equipment must be kept dry, handled with care and stored within the temperature range –20 to +45^{o}C.

Further details on handling and use of the equipment are contained in the product user manuals. A copy of manuals should be taken with the equipment on each field measurement for reference.

I4.2 Equipment List

Quantity	Item	Comments
6	Svantek 948 Sound Level Meter (SLM)	Can record 4 microphones
6	Sets of microphone cables/connectors	For use with SLM, Microphone 1,2,3,4 cable Svantek to BNC connector F/F Svantek to BNC connector M/F BNC cable connector M/M
1	Svantek 948 power supplies	Primary power for SLM
1	Svantek 947 SLM	Backup SLM unit
13	Svantek 1/2 in microphones*	Compatible with 947-948
13	Svantek microphone preamps*	Compatible with 947-948
6	10 ft BNC cables	For remote microphones
6	50 ft BNC cables	For remote microphones
6	100 ft BNC cables	For remote microphones
12	Standard microphone stands	One for each microphone
12	Microphone holders/stand adaptors	For mounting microphones
12	Microphone mounting clips	Used instead of mic stand
24	AA size batteries	Backup power for SLM
1	Laptop with SVEN program	Downloads data from SLM
6	12 ft 3-wire extension cords	Power for SLM adaptors

* Microphones and preamps are matched to a specific SLM channel and labeled accordingly. The SLM has the specific calibration correction for that microphone-preamp combination entered into the corresponding channel.

I4.3 Pre-departure Checks

Verify proper operation of all instruments prior to departure. Make checks sufficiently early so that, if necessary, replacements or suitable substitutes can be obtained. See On-Site Setup and Testing below for detailed instructions on SLM use or refer to the SLM operation manual.

1. Connect one microphone, turn on the SLM, and check for standard startup and full battery level. Replace batteries if level is below full.
2. Ensure data stored on SLM is recorded elsewhere or not needed, then clear all buffers and files.
3. Set up SLM for sound recording on the channel with the microphone.
4. Set up for continuous recording with 10-second integration time and buffer on Lin.
5. Set the display to display the same channel SPL dB.
6. Record sound for a short time (about a few minutes), making some loud noises and observing proper indications on the SLM. Save the file.
7. Check the file by downloading the data to a computer or loading it into the SLM for display.

If you encounter any problems, refer to SLM troubleshooting. Otherwise shut down the SLM and disconnect microphone, preamp, and cables.

I4.4 Packing/Shipping Procedure

Svantek SLMs are somewhat delicate instruments and should be packed surrounded by protective material. One half inch of packing foam in a hard-shell case should be sufficient. Ensure the SLM is held in place and cannot move in the case.

Microphones and preamps are kept together and packed in a bag. That bag is packed with the chs. 1-3 cable, the ch. 4 cable, power adaptors, a 10 ft BNC cable, and connectors in an individually marked bag.

Batteries should be packed in their store or equivalent packaging to avoid electrical shorting.

Other items such as tripods, microphone holders, cables, and Velcro straps are packed in a large case. They should be packed with foam or suitable material to prevent shifting while in transit.

I4.5 On Site Setup

The goal is to take sound recordings from the office space in two locations, one that is at or near a common center of human activity and one that is in a location away from normal activities and more typical of a study or personal work area. Often conditions demand setting both microphones a short distance apart. It may be preferable to locate one microphone near the comfort station and the second microphone as far as safety and non-interference with occupants allows.

Begin the recordings before the start of the workday and continue recording until some time after the end of the workday. The time span should be long enough to capture both the general background sound with no occupants present and the sound levels over a typical workday.

I4.6 Sound Meter Automatic Recording Setup

1. Turn on the meter. To turn on power to the meter, hold down the PROCEED button and press the START button. Refer to the Svantek front panel illustration (Figure I6).

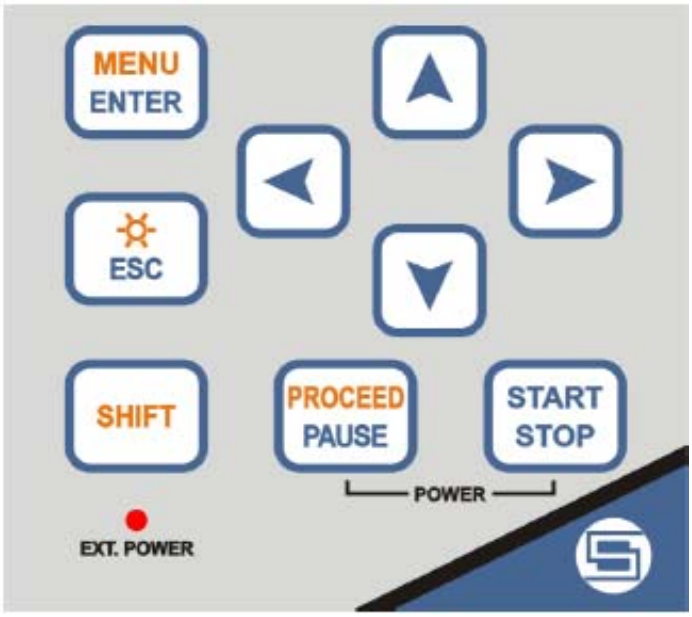


Figure I6. Svantek Front Panel

2. Start a recording by pressing START and check for proper operation. Stop the meter by pressing STOP. Do not save the checkout.
3. Set up the SLM for recording.
4. With SLM on and warm up time expired or skipped, enter the setup menu; Hold down SHIFT and press MENU. Figure I7 illustrates the main menu with different selections highlighted. Highlighted items are selected using the UP or DOWN arrows. Other menus behave similarly.

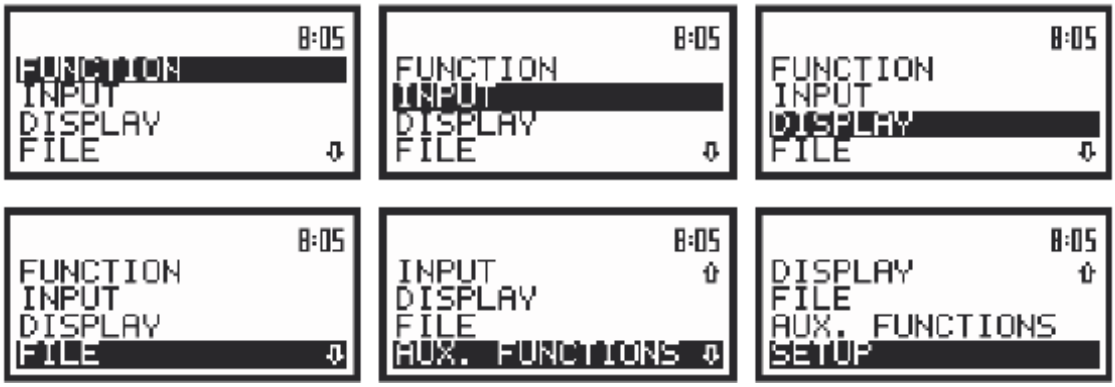


Figure I7. Illustration of Main Menu

5. With FUNCTION highlighted, press ENTER.
6. In the FUNCTION menu, choose MEASUR. FUNCTION by pressing the UP arrow and pressing ENTER.
7. Select 1/3 OCTAVE from the display that appears after step 2 by using the DOWN arrow. It should show 1/3 OCTAVE [*]. Press ENTER.
8. The display will return to MEASUR. FUNCTION.
9. Press ENTER again to confirm that 1/3 OCTAVE is selected.
10. Press ENTER then ESC or ESC twice to return to the MENU display.
11. Select INPUT with the down arrow key and press ENTER.
12. Highlight MEASURE SETUP and press ENTER.
13. Set up the meter to show on the display:
14. START DELAY: 1s
15. INT. TIME : 10h
16. REP. CYCLE: 1
17. BUF. STEP : 10s
18. Press ENTER to enter and go up the menu. Press ENTER again to confirm the settings.
19. Press ENTER or ESC to return to the INPUT display.
20. Highlight CHANNELS SETUP using the DOWN arrow and press ENTER.
21. For a normal two channel setup, setup Channel 1 and Channel 4.

22. Highlight CHANNEL 1 and press ENTER.
23. Set up the meter to show on the display:
24. MODE(1) : SOUND
25. RANGE : 105dB
26. FILTER : LIN
27. DETECT. : FAST
28. Press ENTER. Press ENTER again to verify settings.
29. Press ENTER or ESC to go up the menu to the channel setup display.
30. Highlight CHANNEL 4 and press ENTER. Set up the same as Channel 1.
31. When channel setup is complete, press ESC twice to return to the input display.
32. Highlight BUFFERS SETUP and press ENTER.
33. Select BUFFERS: ON using the arrow keys and press ENTER.
34. Select PEAK, MAX, MIN, or RMS for the channels.
35. Press ENTER to confirm BUFFERS settings.
36. Press ENTER again or ESC to go up the menu to the input setup display.
37. Highlight 1/3 OCTAVE SETUP and press ENTER.
38. Select CHANNEL 1: ON and press ENTER.
39. Set up the meter to show on the display:
40. SPECTRUM
41. FILTER : LIN
42. BUFFER : RMS
43. Then press ENTER. Repress ENTER to verify settings.
44. Repeat for CHANNEL 4.
45. Press ENTER again or ESC to go up the menu to the input setup display.
46. Highlight TRIGGER SETUP and press ENTER.
47. Select TRIGGER: Off and press ENTER.
48. Press ENTER again to confirm then ESC twice to go up to the menu display.
49. Highlight DISPLAY and press ENTER.
50. The display settings do not affect the stored data. It is recommended that you select a display that allows easy monitoring of the data real-time.
51. For example: In DISPLAY MODES, check SPECTRUM, and STATISTICS,. For DISPLAY SETUP, for Channels 1 and 4, select:
52. DISPLAY SCALE
53. SCALE : LOG

54. DYNAMIC : 80dB
55. X-ZOOM : 1x
56. For total values:
57. Select A for 1.
58. Select C for 2.
59. Select LIN for 3.
60. For SPECTRUM TYPE select RMS.
61. Ignore other display setup items.
62. Back in the menu display highlight SETUP and press ENTER. Enter or verify the following settings:
63. Set TIMER to EVERYDAY.
64. Set RTC to the local time and date of the location being monitored (know your time zone).
65. Set FIELD CORRECTION to FREE.
66. For USER FILTERS, set all SOUND filters to 0.0.
67. For STAT. LEVELS, default settings are fine (1, 10, 20, 30, etc.).
68. For EXT. I/O SETUP, set MODE to ANALOG for all channels.
69. For SHIFT MODE:
70. Set SHIFT to SHIFT.
71. Set ST/SP to Normal.
72. Only use CLEAR SETUP to reset the setup.
73. Set RMS INTEGRATION to LINEAR.
74. For REFERENCE LEVEL, set SOUND to 20micro Pa.
75. Set VIBRATION UNITS to METRIC. This does not affect the data.
76. Set WARNINGS to RES. NOT SAVE.
77. Set VECTOR DEF. to1.00 for all. This does not affect sound data.
78. The default settings for HAV/WBV DOSE are fine. They do not affect sound data.
79. The last item is AUX. FUNCTIONS. The default settings are fine. These settings do not affect sound data.
80. Before exiting the setup menu, enter the TIMER settings last (again if already entered previously). Hit ESC to get out of the menu and into the test ready mode. You can always check any settings by reentering the menu mode and selecting the item of interest.

Once out of the menu mode, the SLM returns to whatever display was last up when you entered the menu mode. Because all files and buffers have been cleared, the displays should be blank.

The display selection can be changed with the UP or DOWN keys.

The channel display should show battery status, time, CH 4 (or CH 1), SPL, dB, FAST. You can change the displayed channel by holding SHIFT and pressing the UP or DOWN keys.

Pressing the LEFT or RIGHT keys will change the type of value shown (SEL, Ld, Ltm3, Ltm5, L01, PEAK, MAX, MIN).

If SPECTRUM was checked in DISPLAY MODES, you can click through plots of each channel with the UP or DOWN keys.

The STATISTICS plot is for one channel. Hold down the SHIFT key and press the UP or DOWN keys to change to a different sound channel.

In both the SPECTRUM and STATISTICS plot, clicking the LEFT or RIGHT keys steps along the location of the cursor and the digital readout on the right.

Holding down the SHIFT key and clicking the LEFT or RIGHT keys moves the cursor to either end.

I4.7 Equipment Setup

Review each station for the physical setup possibilities and where microphones can be mounted. Several options exist for the set up:

- One microphone on the comfort station, one clipped to room furniture.
- One microphone on the comfort station, one on a stand.
- One microphone clipped to furniture, one on a stand.
- Both microphones on stands.

Consider pre-mounting the microphones on the comfort stations. Pre-mounting may speed up setup in the room where recording is done. If needed, consider pre-building the microphone stands. This depends on the ease of carrying a built-up stand to the test room and the amount of interference setup in the test room will cause occupants.

Be careful to avoid locating directly at a dominant noise-generating device such as directly below a noisy register or a loud printer. The SLM can be located on a cabinet, desk or on the floor near the number 4 microphone. Select a location, being careful to choose a location where the SLM could get knocked onto the floor, kicked, or stepped on.

Run cable to the remote microphone, routing the cable to avoid trip hazards or cable pulling. Tape down cables as necessary. Use channels 1 and 4 for the microphones, being sure to match the microphones with the proper channel. The channel 1 cable can be extended using the BNC cables. Pick an appropriate length of cable. Do not exceed 100 ft. Because channel 4 has the shorter cable, that microphone is normally situated with or near the comfort station.

I4.8 Office Sound Data Recording

Once setup is complete, running the test should entail only placing the turned off SLM in the proper location and monitoring as desired.

Confirm the start time for testing with the test team.

If the meter was set up properly and functions properly, it will come on automatically and start recording data after the warm-up delay.

Check the display for proper operation.

The time display will change to a count of the time passed in that integration time (10 hours).

A small speaker icon with waves will appear on the top of the display showing that data is being taken as shown below.

If a bell icon appears instead, check system settings. This is a warning for things such as low battery or high input signal.

If the meter does not come on at the proper time, manually turn on the meter and check the settings for accuracy. Push start to start the recording.

In some cases, a meter will turn on at the proper time but fail to start recording.

Push start to start the recording.

In that case, the meter will run for the programmed time, stop recording but not shut down.

It may or may not save the data.

If you encounter this problem, check if the data was saved and manually save if necessary before starting the next days recording or shutting down.

When testing is complete, the meter should stop, save the recording, and shut down automatically.

If automatic shutdown does not occur, if the meter is still recording, press the START STOP key to stop the recording. The meter should then automatically save the recording.

If not, manually save the recording with a unique name.

1. Record the data into the SLM memory using the FILE menu.
2. Hold the SHIFT key and press MENU
3. Highlight FILE and press ENTER
4. Highlight SAVE and press ENTER
5. The display shows SAVE and the date as DDMMM. Press ENTER
6. The display shows FILE NAME and the date. Enter a number after the date to have a unique file name, such as 01JAN01.
7. Use the LEFT and RIGHT arrow keys to move the cursor and the UP and DOWN arrow keys to select numbers or letters for the file name.
8. Press ENTER to save the file.

The display should show file saved, and the file name.

Check meter settings for accuracy and redo the setup as necessary.

You can now turn off the SLM or start a new test. The saved test data will remain in the SLM memory until you delete it.

WARNING! Do not turn off the SLM prior to saving the data. All data will be lost.

I4.9 Packing/Shipping Procedure For Return To UNLV Or Next Building.

Use the same caution and procedures detailed in Packing/Shipping for departure.

I5. CALCULATION ALGORITHMS

Sound algorithms were developed by Verdi Technology Associates.

I5.1 dBA Bumps

dBA Bumps examine sound power levels at various octave band/frequencies and describes the identification and extent that each level exceeds that of its neighbors. A level that exceeds that of its neighbors by the specified amount will be identified with a value of 1, otherwise its value will be 0.

dBA values will be calculated at various frequencies and with the specified amounts of 4, 6 and 8.

Table I1 describes the data field names for storing the various values.

Table I1. Data Field Names for Storing Values

Description	Field Name	Columns
1/1 octave band, 4dB variance	DBA11_63_6 through DB11_4000_4	7
1/1 octave band, 6dB variance	DBA11_63_6 through DB11_4000_6	7
1/1 octave band, 8dB variance	DBA11_63_6 through DB11_4000_8	7
1/3 octave band, 4dB variance	DBA13_63_6 through DB13_8000_4	22
1/3 octave band, 6dB variance	DBA13_63_6 through DB13_8000_6	22
1/3 octave band, 8dB variance	DBA13_63_6 through DB13_8000_8	22

For L = the measured dB for each subject frequency, x = the sequential position the data are located in the sample row and R = the result:

$$\text{If } L_x >= L_{x-1} + 8 \text{ And } L_x >= L_{x+1} + 8 \text{ Then } R = 1 \text{ Else } R = 0$$

I5.2 NC – Noise Criteria

NC calculations reference a standard table of reference values by NC value and frequency as:

	NC	63Hz	125Hz	250Hz	500Hz	1000Hz	2000Hz	4000Hz	8000Hz
L_ref	10	43	32	26	18	11	9	8	7
L_ref	20	50	40	34	27	21	19	18	17
L_ref	30	57	48	42	36	31	29	28	27
L_ref	40	64	56	50	45	41	39	38	37
L_ref	50	71	64	58	54	51	49	48	47
L_ref	60	78	72	66	63	61	59	58	57

L_ref	70	85	80	74	72	71	69	68	67
L_ref	80	92	88	82	81	81	79	78	77
L_ref	90	99	96	90	90	91	89	88	87
L_ref	100	106	104	98	99	101	99	98	97
L_ref	110	113	112	106	108	111	109	108	107
Correction	10	7	8	8	9	10	10	10	10

Values granular to 1dB are calculated by interpolation or by using the following formula:

$$L_{ref} = Lref_{NC10} + Corr_{freq}/10 * (Lref_{NC} - 10)$$

Where $Lref_{NC10}$ is the base value shown in the first (NC = 10) row of the table, $Corr_{freq}$ is the Correction for the selected frequency, (divided by the base value $Corr_{NC}$ of 10) and NC is the selected NC level, (or row).

Therefore, the L_{ref} for an NC of 80 at 500Hz would be:

$$18 + 9/10 * (80 - 10) \quad \text{or} \quad 81$$

The L_{ref} for an NC of 105 at 63Hz would be:

$$44 + 7/10 * (105 - 10) \quad \text{or} \quad 110.5$$

For each sample, the lowest NC row possible is chosen where all 1/1 octave band levels from 63 to 8000Hz are at or below those shown in the table: Consider the following table excerpt and sample measurement:

	NC	63Hz	125Hz	250Hz	500Hz	1000Hz	2000Hz	4000Hz	8000Hz
L_ref	51	72.7	64.8	58.8	54.9	52	50	49	48
L_ref	52	73.4	65.6	59.6	55.8	53	51	50	49
L_ref	53	74.1	66.4	60.4	56.7	54	52	51	50
L_x		30	40	50	55	50	48	38	30

In this case an NC of 52 is the highest permissible row as the 500Hz level of 55 becomes the first value that would exceed L_{ref} value at NC = 51.

Once the appropriate row of the table is determined, a value for each frequency in the sample is determined as:

$$NC + 10/Corr_{freq} * (L_x - L_{ref})$$

Where NC is the lowest NC selected in the prior paragraph, $Corr_{freq}$ is the Correction for the selected frequency taken from the table, L_x is the measured level for the frequency and L_{ref} is the value shown in the table for the NC and the frequency.

$$63Hz = 52 + 10/7 * (30 - 73.4) = -10.00$$

$$125Hz = 52 + 10/8 * (40 - 65.6) = 20.00$$

250Hz = 52 + 10/8 * (50 – 59.6) = 40.00

500Hz = 52 + 10/9 * (55 – 55.8) = 51.11

1000Hz = 52 + 10/10 * (50 – 53) = 49.00

2000Hz = 52 + 10/10 * (48 – 51) = 49.00

4000Hz = 52 + 10/10 * (38 – 50) = 40.00

8000Hz = 52 + 10/10 * (30 – 49) = 33.00

These NC values are shown as:

	63Hz	125Hz	250Hz	500Hz	1000Hz	2000Hz	4000Hz	8000Hz
L_x	30	40	50	55	50	48	38	30
NC value	-10.00	20.00	40.00	51.11	49.00	49.00	40.00	33.00

The highest calculated NC value is 51.44 which will be stored in the NCMax field and the frequency, 500 will be stored in the NCFreq field. In the event of a tie, any frequency having the highest value can be saved as the NCFreq.

I5.3 NCB – Balanced Noise Criteria - Rumble

The Balanced Noise Criteria (BNC) is used to analyze for rumble and hiss. Both criteria use a standard table appearing as:

	NCB	16Hz	31.5Hz	63Hz	125Hz	250Hz	500Hz	1000Hz	2000Hz	4000Hz	8000Hz
L_ref	10	69	61	40	31	22	15	12	8	5	2
L_ref	20	74	66	47	39	31	25	22	18	15	12
L_ref	30	79	71	54	47	40	35	32	28	25	22
L_ref	40	84	76	61	55	49	45	42	38	35	32
L_ref	50	89	81	68	63	58	55	52	48	45	42
L_ref	60	94	86	75	71	67	65	62	58	55	52
L_ref	70	99	91	82	79	76	75	72	68	65	62
L_ref	80	104	96	89	87	85	85	82	78	75	72
L_ref	90	109	101	96	95	94	95	92	88	85	82
L_ref	100	114	106	103	103	103	105	102	98	95	92
L_ref	110	119	111	110	111	113	115	112	108	105	102
Correction	10	5	5	7	8	9	10	10	10	10	10

NCB values as granular as 1 dB are calculated either by interpolation or by using the formula:

$$L_{freq} = Lref_{10} + Corr_{freq}/10 * (Lref_{NCB} - 10)$$

The L_{freq} for an NCB of 70 at 250Hx would be:

26 + 8/10 * (70 - 10) or 74

The L_{freq} for an NCB of 64 at 63Hx would be:

40 + 7/10 * (64 - 10) or 77.8

To determine rumble, first SIL is calculated as follows:

SIL = Round(Avg(H1_500 + H1_1000 + H1_2000 + H1_4000))

Which means that SIL is the average of the 1 /1 octave band levels for the 500, 1000, 2000 and 4000Hz frequencies rounded to the nearest integer. The non-rounded value is stored as SIL.

SIL is then used to select an NCB row from the above level. (SIL = NCB) If ANY of the measured 1 /1 octave band levels from 16 to 500Hz is more than 3dB above the values shown in the table, the sample is said to have rumble.

The rumble value will be stored in a field named NCBRumble as a 1 if rumble exists, otherwise as a 0.

I5.4 NCB – Balanced Noise Criteria - Hiss

The Hiss calculation uses a simplified least squared fit to match the lower frequencies (125, 250 and 500Hz) in a sample to the referenced NCB table above and then examines some of the higher frequencies to determine whether Hiss is present.

A number is calculated using the sample measurement for each row of the table as follows:

$$FIT = (L_{ref\_125Hz} - Lx_{\_125Hz})^2 + (Lref_{\_250Hz} - Lx_{\_250Hz})^2 + (Lref_{\_500Hz} - Lx_{\_500Hz})^2$$

The row exhibiting the smallest FIT value is chosen for the next step and the reference NCB is stored as NCBRefHiss.

Consider the following case:

	NCB	125Hz	250Hz	500Hz	Calculation	FIT
L_ref	37	52.6	47.6	42	(52.6 – 50)^2 + (47.6 – 50)^2 + (42 – 44)^2	16.52
L_ref	38	53.4	48.4	43	(53.4 – 50)^2 + (48.4 – 50)^2 + (43 – 44)^2	15.12
L_ref	39	54.2	49.2	44	(54.2 – 50)^2 + (49.2 – 50)^2 + (44 – 44)^2	18.28
Lx		50	50	44		

In this excerpt the lowest FIT number is 15.12. (All other values not shown are higher.) Therefore the NCB of 38 is the best fit and 38 is stored in the NCBRef_Hiss field.

Higher frequencies are then compared using the selected NCB row:

	NCB	1000Hz	2000Hz	4000Hz
L_ref	38	40	36	33
Lx		40	40	32

If any of the sample levels in the 1000, 2000 or 4000Hz bands are higher than those shown in the selected NCB row, the sample is said to have hiss. This value is stored in a field named NCBHiss as a 1 if hiss exists, otherwise as a 0. In this case we store a 1 as the measured 2000Hz level is above the reference level.

I5.5 RC – Room Criteria

Similarly to prior derivatives, room criteria (RC) relies on a standard table for many of its calculations:

				Rumble					Hiss	
	RC	16Hz	31.5Hz	63Hz	125Hz	250Hz	500Hz	1000Hz	2000Hz	4000Hz
RC_ref	10	40	35	30	25	20	15	10	5	0
RC_ref	20	50	45	40	35	30	25	20	15	10
RC_ref	30	60	55	50	45	40	35	30	25	20
RC_ref	40	70	65	60	55	50	45	40	35	30
RC_ref	50	80	75	70	65	60	55	50	45	40
RC_ref	60	90	85	80	75	70	65	60	55	50
RC_ref	70	100	95	90	85	80	75	70	65	60
RC_ref	80	110	105	100	95	90	85	80	75	70
RC_ref	90	120	115	110	105	100	95	90	85	80

Note that the 16Hz band is not used for RC calculations, but will be used for the RCII calculations further on.

The Correction factor for the RC and for every value is always 10.

RC values as granular as 1 dB are calculated either by interpolation or by using the formula:

$$RC_{ref} = RC_{Freq10} + (RC - 10)$$

The RC_{ref} for an RC of 70 at 250Hz would be:

$$25 + (70 - 10) \quad \text{or} \quad 85$$

The RC_{ref} for an RC of 64 at 63Hz would be:

$$35 + (64 - 10) \quad \text{or} \quad 89$$

An RC value for each sample line is calculated as:

RC = Round (Avg(H1_500 + H1_1000 + H1_2000)

Which means that RC is the average of the 1 /1 octave band levels for the 500, 1000 and 2000Hz frequencies rounded to the nearest integer. The non-rounded value is stored as RC.

Using the following sample:

	31.5Hz	63Hz	125Hz	250Hz	500Hz	1000Hz	2000Hz	4000Hz
L_x	32	41	40	72	55	50	48	38

The RC value is calculated as:

Round(Avg(55 + 50 + 48)) = 51

A table excerpt for a RC of 51 is:

				Rumble				Hiss	
	RC	31.5Hz	63Hz	125Hz	250Hz	500Hz	1000Hz	2000Hz	4000Hz
RC_freq	51	81	76	71	66	61	54	51	46

If any sample value exceeds the table value within the range of 31.5 to 500Hz by 5 or more dB then rumble exists. In this case, the 250Hz value of 72 exceeds 66 in the table by 6 dB so the field RCRumble is set to 1.

When any of the values in the 1000 through 4000Hz frequency range exceed the table by 3dB or more, the sample is said to have hiss and the RCHiss field is set to 1. The above sample does not have hiss.

If both the RCRumble and RCHiss fields are 0, the sample is considered neutral.

I5.3.1 RC Mark II (RCII - f(31.5Hz band to 4000Hz band)

RCII is used to determine quality descriptors for low frequency rumble, medium frequency roar and high frequency hiss.

RCII uses the same table as that of RC and is inclusive of the 16Hz band

An RCII for each sample line is calculated the same way that RC, above is as:

RCII = Round (Avg(H1_500 + H1_1000 + H1_2000)

Using the following sample:

	16Hz	31.5Hz	63Hz	125Hz	250Hz	500Hz	1000Hz	2000Hz	4000Hz
L_x	70	70	68	65	61	58	54	50	38

RCII is calculated as:

Round(Avg(58 + 54 + 50)) = 54

The table excerpt for an RCII of 54, (and the measured values) are:

				Rumble					Hiss	
	RCII	16Hz	31.5Hz	63Hz	125Hz	250Hz	500Hz	1000Hz	2000Hz	4000Hz
RC_ref	54	84	79	74	69	64	59	54	49	44
		70	70	68	65	61	58	54	50	38

First differences or 'delta' values for 3 of the low frequency bands are calculated as:

$\Delta L_{16} = L_{M16} - L_{RCII16} = 70 - 84 = 14$

$\Delta L_{31.5} = L_{M31.5} - L_{RCII31.5} = 70 - 79 = -9$

$\Delta L_{63} = L_{M63} - L_{RCII63} = 68 - 74 = -6$

A cumulative low frequency delta is calculated as:

$\Delta LF = 10 * \text{Log10}\,(1/3 * (10\text{^}(\Delta L_{16}/10) + 10\text{^}(\Delta L_{31.5}/10) + 10\text{^}(\Delta L_{63}/10)))$

$= 10 * \text{Log10}(1/3 * (10\text{^}(-14/10) + 10\text{^}(-9/10) + 10\text{^}(-6/10)))$

$= 8.571$

Calculations for the medium frequency are processed similarly:

$\Delta L_{125} = L_{M125} - L_{RCII125} = 65 - 69 = -4$

$\Delta L_{250} = L_{M250} - L_{RCII250} = 61 - 64 = -3$

$\Delta L_{500} = L_{M500} - L_{RCII500} = 58 - 59 = -1$

A cumulative medium frequency delta is calculated as:

$\Delta MF = 10 * \text{Log10}\,(1/3 * (10\text{^}(\Delta L_{125}/10) + 10\text{^}(\Delta L_{250}/10) + 10\text{^}(\Delta L_{500}/10)))$

$= 10 * \text{Log10}\,(1/3 * (10\text{^}(-4/10) + 10\text{^}(-3/10) + 10\text{^}(-1/10)))$

$= 2.483$

As is the calculations for the high frequency:

$\Delta L_{1000} = L_{M1000} - L_{RCII1000} = 54 - 54 = 0$

$\Delta L_{2000} = L_{M2000} - L_{RCII2000} = 50 - 49 = 1$

$\Delta L_{4000} = L_{M4000} - L_{RCII4000} = 38 - 44 = -6$

A cumulative medium frequency delta is calculated as:

$\Delta HF = 10 * \text{Log10}\,(1/3 * (10\text{^}(\Delta L_{1000}/10) + 10\text{^}(\Delta L_{2000}/10) + 10\text{^}(\Delta L_{4000}/10)))$

$= 10 * \text{Log10}\,(1/3 * (10\text{^}(0/10) + 10\text{^}(1/10) + 10\text{^}(-6/10)))$

$= -0.774$

The selected RCII reference level is stored in the RCII field. (54)

The cumulative frequency deltas are stored in the DeltaLF, DeltaMF and DeltaHF fields. (-8.571, -2.483 and –0.774)

The largest difference between any pair of DeltaLF, DeltaMF and DeltaHF fields is stored as DeltaMAX (QAI).

If DeltaMax is less than or equal to 5, RCIIQual is set to 0. Otherwise RCIIQual is set to; 1 if the DeltaLF field is highest, 2 if DeltaMF is highest and 3 if DeltaHF is highest. If there is a 2 way tie for highest, RCIIQual is set to the lower of the two possible values.

I5.4 CPL - Cumulative Probability Levels

Cumulative probability levels are calculated for dBA, dBC, dBC_dBA, NCMax, RC and SIL measures. In each case both a consolidated set of data for the overall building is generated plus sets of data for each MinorLocationID that was documented.

To calculate CPLs, the data for the specific measure will be ordered from the lowest value, (L_00) to the highest value, (L_100). The following cumulative probabilities will be calculated:

10. L_99
11. L_95
12. L_90
13. L_80
14. L_50
15. L_33
16. L_10
17. L_05

For example the L_99 value is that value where 99% (as closely as possible) of the samples fall at or below the value and 1% of the samples are above. L_50 is similar to the statistical median of the sample but not exact as this method does not interpolate between values.

dBA is the raw SPL_A reading taken directly from the table.

dBC is the raw SPL_A reading taken directly from the table.

dBC_dBA is the raw SPL_A minus the raw SLP_C reading taken directly from the table.

NCMax is the reference value for the lowest row chosen from the NC reference table. (NCRef)

RC is the Avg(H1_500 + H1_1000 + H1_2000) as previously described. (RC)

SIL is the Avg(H1_500 + H1_1000 + H1_2000 + H1_4000) as previously described. (SIL)

I6. SUMMARY OF CALCULATED VALUES

I6.1 dBA Bumps

Used to describe sound level measurements for various frequencies that exceed the levels of their immediate neighbors by the variances shown below. Items that equal or exceed the variance are identified with the value of 1 otherwise they contain the value of 0 (Integer).

dBC – See SPL_C in raw data (Float)

dBC - dBA – Use SPL_C - SPL_A in raw data (Float)

I6.2 NC – Noise Criteria

NC selects the highest measured sound level that fits within a standardized sound level.

NCMax stores the maximum sound level found. (Float)

NCFreq stores the frequency where this sound level was found. (Integer)

I6.3 NCB – Balanced Noise Criteria

NCB is one method to determine if rumble and hiss exist in a sound sample.

SIL stores the Sound Interface Level used to select the NCB reference level for rumble (Float)

NCBRumble stores a 1 if rumble is detected otherwise a 0 (Integer)

NCBRefHiss stores the NCB reference level for hiss (Integer)

NCBHiss stores a 1 if hiss is detected otherwise a 0 (Integer)

I6.4 RC – Room Criteria

RC stores the RC table level that is used for analyzing hiss and rumble (Float)

RCRumble stores a 1 if rumble is detected otherwise a 0 (Integer)

RCHiss stores a 1 if hiss is detected otherwise a 0 (Integer)

I6.5 RC Mark II (RCII) Alternate Room criteria

RCII is another derivative that analyzes rumble, hiss and an intermediate quality descriptor named roar.

RCII stores the RC table level that is used for analyzing hiss, rumble and roar (Integer)

DeltaLF stores a cumulative difference between the table and the measured low freq values (Float)

DeltaMF stores a cumulative difference between the table and the measured med freq values (Float)

DeltaHF stores a cumulative difference between the table and the measured high freq values (Float)

RCIIQual stores the indicator for the highest Delta, 0=none, 1=LF, 2=MF, 3=HF, whenever DeltaMax is greater than 5 (Integer)

DeltaMax (QAI) stores the largest difference between any pair of Deltas above (Float)

I6.6 CPL - Cumulative Probability Levels

CPL defines a level for a measurement where a specified percentage of the samples fall at or below the indicated percentage. The following table shows how to construct the eight field names for the each of the four measurements, dBA, dBC, dBC_dBA, NCMax, RC and SIL:

Prefix	Suffixes					
L_99_	dBA	dBC	dBC_dBA	NCMax	RC	SIL
L_95_	dBA	dBC	dBC_dBA	NCMax	RC	SIL
L_90_	dBA	dBC	dBC_dBA	NCMax	RC	SIL

L_80_	dBA	dBC	dBC_dBA	NCMax	RC	SIL
L_50_	dBA	dBC	dBC_dBA	NCMax	RC	SIL
L_33_	dBA	dBC	dBC_dBA	NCMax	RC	SIL
L_10_	dBA	dBC	dBC_dBA	NCMax	RC	SIL
L_05_	dBA	dBC	dBC_dBA	NCMax	RC	SIL

dBA is raw SPL_A data taken form the samples (Float)

dBA is raw SPL_C data taken form the samples (Float)

dBA_dBA is raw SPL_C minus the raw SLP_A data taken form the samples (Float)

NCMax is the calculated sound level from the NC sections above (Float)

RC is the value stored in the RC sections above (Float)

SIL is the value stored in the NCB sections above (Float)

APPENDIX J: LIGHTING PROTOCOLS

J1. DESCRIPTION OF INSTRUMENTS

J1.1 Illuminance Meter T-10

Table J1. Summary of the features of the meter used to record illuminance.

Make	Konica Minolta
Model	T-10 Multi-function digital illuminance meter with detachable receptor
Receptor	Silicon photocell
Relative spectral response	Within 8% (f1') of the CIE spectral luminous efficiency V(λ)
Cosine correction characteristics	Within ±1% at 10°; Within ±2% at 30°; Within ±6% at 50°; Within ±7% at 60°; Within ±25% at 80°
Measuring range	Auto range (5 manual ranges for analog output)
Measuring functions	Illuminance (lx, fcd); Illuminance difference (lx, fcd); Illuminance ratio (%); Integrated illuminance (lx.h, fcd.h); Integration time (h); Average illuminance (lx, fcd)
Measurement range	Illuminance: 0.01 to 299,900lx (0.001 to 29,990fcd) Integrated illuminance: 0.01 to 999,900 x 103lx.h (0.001 to 99,990 x 103fcd.h); 0.001 to 9,999h
User calibration function	CCF (Color Correction Factor) setting function
Accuracy	±2% ±1 digit of displayed value (based on Konica Minolta standard)
Temperature/humidity drift	Within ±3% ±1 digit (of value displayed at 20°C/68°F) within operating temperature/humidity range
Digital output	RS-232C
Analog output	1mV/digit, 3V at maximum reading; Output impedance: 10kΩ; 90% response time: FAST setting: 1ms, SLOW setting: 1s
Display	3- or 4-significant-digit LCD with backlight illumination
Operating temperature /humidity range	-10 to 40°C, relative humidity 85% or less (at 35°C) with no condensation
Storage temperature /humidity range	-20 to 55°C, relative humidity 85% or less (at 35°C) with no condensation
Power source	2 AA-size batteries / AC adapter (optional)
Battery life	72 hours or longer (when alkaline batteries are used) in continuous measurement
Dimensions	69 x 174 x 35mm (2-3/8 x 6-7/8 x 1-7/16 in.)
Weight	200g (7.0 oz.) without batteries
Standard accessories	Ø3.5mm (Ø1/8 in.) subminiature plug for analog output; Receptor cap; Neck strap; Case; Batteries
Optional accessories	Receptor head; Adapter Unit for Main Body; Adapter Unit for Receptor Head; AC Adapter; Data Processing Software

Names and Functions of Parts

This section is limited to discussion of the parts be used in this task. The following are features of the meter (Figure J1):

1. Receptor window.
2. Display window.
3. Response speed selector switch. This feature switches between FAST and SLOW. The FAST mode is used to measure a normal light source such as daylight, lamplight and fluorescent light. The SLOW mode is used to measure average illuminance of a flicker light such as a movie projector, video projector and TV screen.
4. Tripod fixing screw hole.
5. Power switch.
6. Battery cover.

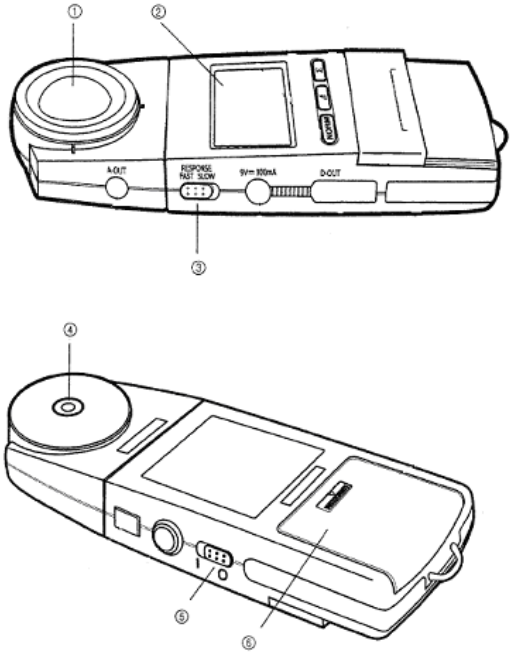


Figure J1. Illuminance Meter T-10.

Basic Operation

1. Uncover the receptor window
2. Set the power switch to "I" (ON). The illuminance value will be shown in the display widow.

Notes on Use

18. Take care not to scratch or allow the receptor window to get dirty. If you are not going to use it, attach the cap.
19. If the receptor window gets very dirty, wipe it gently with a soft dry cloth. If the dirt cannot be removed or the receptor window is scratched, contact the nearest KONICA MINOLTA SENSING-authorized service facility.
20. This instrument should be stored at temperatures of between 20° and 55°C at ≤85% RH. Do not leave the instrument near the rear window or inside the trunk of a car. Under strong sunlight, the increase in temperature can be extreme and may result in breakdown or deformation. If you are not going to use the instrument for two or more weeks, remove the batteries from the instrument. Failure to do so may cause leakage of electrolyte, resulting in damage to the instrument.

J1.2 Luminance Meter LS-100

Table J2. Summary of the features of the meter used to monitor luminance.

Make	Konica Minolta
Model	LS 100 Digital SLR spot luminance meter
Acceptance angle	1°
Optical system	85mm f/2.8
Angle of view	9°
Focusing distance	1014mm (40 in.) to infinity
Minimum measuring area	Ø14.4mm
Measurement distances (areas) with close-up lenses	Close-Up Lens No.153: 623mm to 1,210 (Ø18.7 to Ø8.0mm) No.135: 447mm to 615 (Ø5.2 to Ø8.7mm) No.122: 323mm to 368 (Ø3.2 to Ø4.3mm) No.110: 203mm to 205 (Ø1.3 to Ø1.5mm)
Receptor	Silicon photocell
Relative spectral response	Within 8% (f1') of the CIE spectral luminous efficiency V(λ)
Response time	FAST: Sampling time: 0.1s, Time to display: 0.8 to 1.0s; SLOW: Sampling time: 0.4s, Time to display: 1.4 to 1.6s
Luminance units	cd/m² or fL (switchable)
Measuring range	FAST: 0.001~299,900cd/m² (0.001 to 87,530fL) SLOW: 0.001~49,990cd/m² (0.001 to 14,590fL)
Accuracy	0.001 to 0.999 cd/m² (or fL): ±2% ±2 digits of displayed value 1.000 cd/m² (or fL) or higher: ±2% ±1 digit of displayed value (Illuminant A measured at ambient temperature of 20 to 30°C/68 to 86°F)
Repeatability	0.001 to 0.999 cd/m² (or fL): ±0.2% ±2 digits of displayed value 1.000 cd/m² (or fL) or higher: ±0.2% ±1 digit of displayed value (Measurement subject: Illuminant A)
Temperature/humidity drift	Within ±3%, ±1 digit (of value displayed at 20°C/68°F) within operating temperature humidity range
Calibration mode	Konica Minolta standard or user-selected standard (switchable)
Color correction factor	Set by numerical input; Range: 0.001 to 9.999
Reference luminance	1; set by measurement or numerical input
Measurement modes	Luminance, luminance ratio, peak luminance, or peak luminance ratio
Display	External: 4-digit LCD with additional indications Viewfinder: 4-digit LCD with LED backlight
Data communication	RS-232C; Baud rate: 4,800bps
External control	Measurement process can be started by external device connected to data output terminal
Power source	One 9V battery; Power can also be supplied by optional Data Printer DP-10
Power consumption	While measuring button is pressed and viewfinder display is lit: 16mA average While power is on and viewfinder display is not lit: 6mA average
Operating temperature/humidity range	0 to 40°C, relative humidity 85% or less (at 35°C) with no condensation

Storage temperature/humidity range	-20 to 55°C, relative humidity 85% or less (at 35°C) with no condensation
Dimensions	79 x 208 x 150mm (3-1/8 x 8-3/16 x 5-7/8 in.)
Weight	850g (30 oz.) without battery
Standard accessories	Lens cap; Eyepiece cap; ND eyepiece filter; 9V battery; Case

Names and Functions of Parts

This section is limited to discussion of the parts used for this task.

The following are features of the meter (Figure J2):

1. Distance scale.
2. Measuring trigger. This feature collects a measurement when the trigger is pulled in and measurements are continuously made while trigger is held in.
3. Power switch. This switches the meter ON and OFF.
4. External display.
5. Eyepiece.
6. Measuring mode selector switch.
7. Response speed selector switch. This feature switches between FAST and SLOW. The FAST mode is used to measure a normal light source such as daylight, lamplight and fluorescent light. The SLOW feature is used to measure average illuminance of a flicker light such as a movie projector, video projector and TV screen.
8. Focal-plane indication.
9. Tripod socket.
10. Handgrip.
11. Wrist strap.

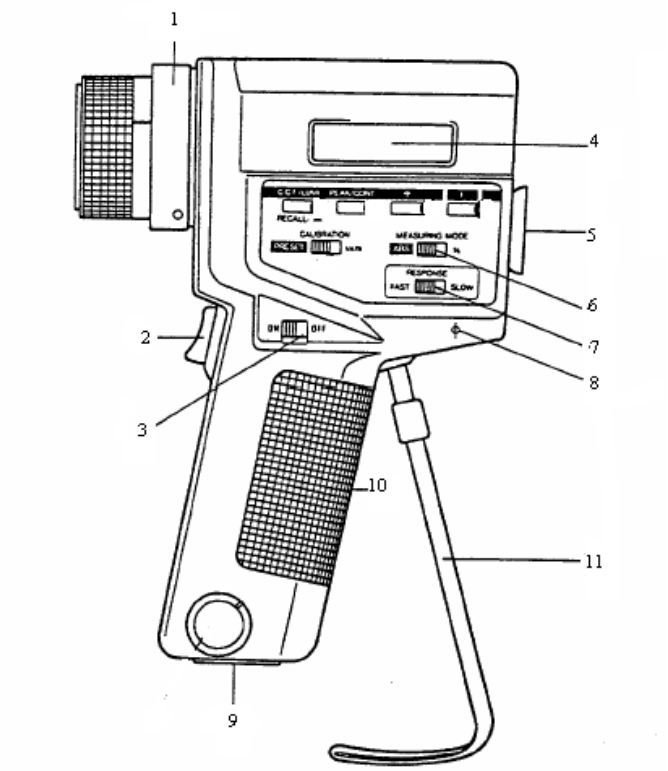


Figure J2. Luminance Meter LS-100

Basic Operation

1. Slide power switch to ON.
2. Set the MEASURING MODE selector switch to ABS.
3. Aim the LS-100 at the subject and turn the focusing ring until the subject appears sharp.

4. Pull the measuring trigger and hold it in until the luminance value appears in the viewfinder display (approximately 2 seconds at FAST response speed or 4 seconds at SLOW response speed). The luminance value will also be shown in the external display.
5. Read the number on the display window.

Notes on Use

1. When taking measurements, be sure that subject fills the measurement area. If the subject does not fill measurement area, move closer and refocus. Measurements of subjects smaller than the measurement area will not be accurate.
2. Measuring-mode information (e.g. cd/m2) will appear and measured values will not be displayed if the measuring trigger is released before the measurement has been completed.
3. The viewfinder display will automatically turn off approximately 5 seconds after the trigger is released.
4. If the meter is mounted on a tripod for extended metering and there is a bright light source near the viewfinder, meter readings may be affected by this light source. Cover the eyepiece with the included eyepiece cap whenever measurements will be taken without looking through the viewfinder.
5. If the LS-100 is being used to measure a CRT, do not place the meter closer than 8 inches from the CRT.

J1.3 Chroma Meter CS-100A

Table J3. Summary of the features of the meter used to monitor light source and surface luminance and chromaticity.

Make	Konica Minolta
Type	CS-100A SLR spot colorimeter for measuring light-source and surface luminance and chromaticity
Acceptance angle	1°
Optical system	85mm f/2.8 lens; SLR viewing system; flare factor less than 1.5%
Angle of view	9° with 1° measurement area indication
Focusing distance	1014mm (40 in.) to infinity
Receptors	3 silicon photocells filtered to detect primary stimulus values for red, green, and blue light Spectral response Closely matches CIE 1931 Standard Observer curves $(\bar{x}2\lambda, \bar{y}\lambda, \bar{z}\lambda)$
Response time	FAST: Sampling time: 0.1s, Time to display: 0.8 to 1.0s; SLOW: Sampling time: 0.4s, Time to display: 1.4 to 1.6s Luminance units: cd/m² or fL (switchable)
Measuring range	FAST: 0.01 to 299,000cd/m² (0.01 to 87,530fL); SLOW: 0.01 to 49,900cd/m² (0.01 to 14,500fL)
Accuracy	Luminance (Y): ±2% of reading ±1 digit Chromaticity (x,y): ±0.004 (Illuminant A measured at ambient temperature of 18 to 28°C/64 to 82°F)
Repeatability	Luminance (Y): ±0.2% of reading ±1 digit Chromaticity (x,y): FAST: Y 100cd/m² or above: ±0.001; 48.1 to 99.9cd/m²: ±0.002; Below 48.1cd/m²: Below measurement range SLOW: Y 25.0cd/m² or above: ±0.001; 12.0 to 24.9cd/m²: ±0.002; Below 12.0cd/m²: Below measurement range (Measurement subject: Illuminant A)

Target value	1; set by measurement or numerical input
Measurement modes	Absolute color: Yxy; Color difference: Δ(Yxy)
Display	External: LCD; 3 values (Y, x, and y) of 3 digits each with additional indications Viewfinder: 3-digit LCD (showing luminance value y) with LED backlight
Data communication	RS-232C; baud rate: 4800bps
External control	Measurement process can be started by external device connected to data output terminal
Power source	One 9V battery; Power can also be supplied via data output terminal
Operating temperature/humidity range	0 to 40°C, relative humidity 85% or less (at 35°C) with no condensation
Storage temperature/humidity range	-20 to 55°C, relative humidity 85% or less (at 35°C) with no condensation
Dimensions (W x H x D)	79 x 208 x 154mm (3-1/8 x 8-3/16 x 6-1/16 in.)
Weight	890g (2 lb.) without battery
Standard accessories	Lens cap; Eyepiece cap; Protective filter; ND eyepiece filter; 9V battery; Chromaticity chart; Case

The exterior appearance, names and functions of parts, basic operation procedures, and notes on use of Chroma Meter CS-100A are exactly the same as the Luminance Meter LS-100 (see Section J3.2 above). The only difference between these two meters is that the values of luminance and chromaticity coordinates x and y will be shown on the display window by the Chroma Meter CS-100A, but only luminance will be shown on the display window of the Luminance Meter LS-100.

J1.4 Spectroradiometer

Table J4. Summary of the features of the meter.

Make	GregtagMacbeth
Model	LightSpex
Spectral Range	360nm to 750nm
Spectral Bandwidth / Accuracy	4nm (FWHM) / ± 0.2 nm
Illuminant Calibrations	A (2856K) and D65 (6500K) Standard
Wavelength Resolution	1.7 nm / pixel
Illuminance Range / Accuracy	~ 0.1-10,000 fc / ±2% Traceable to NIST* at A & D65
Observer Functions	(CMFs) 5 nm, CIE 1931 2deg & CIE 1964 10deg Supported
Repeatability	± 0.1% Short Term ± 0.5% Long Term
Chromaticity	± .001 xy at 2856K and 6500K
Color Temperature Accuracy	± 25K at 2856K and 6500K
Dimensions	4”H x 4”W x 8”D (10x10x20 cm)
Weight	3.5 lbs. (1.6 kg) Battery Included
Operating Temperature	45°F to 90°F (5°C to 32°C)
NIST* Traceable Calibration	6 Month Recommended Interval
I/O	RS-232 and Type II PCMCIA

Names and Functions of Parts

This section is limited to discussion of the parts that will be used in this task. The following are features of the meter:

1. Top Handle.
2. Cosine Receptor with the Dust Cap uncovered. Cosine Receptor is a precision optical element. This element should be kept covered with a Dust Cap unless measurement is being taken.
3. Display Window. The Display Window shows all menus and screens and provides the labels for the Softkeys.
4. Softkeys. There are four Softkeys, with the numbers from 1 to 4. Softkeys activate a variety of system functions. Keys re assigned to operate only with the current screen.
5. Power switch. Toggle the switch to the "1" position to turn the instrument ON; toggle it to the "0" position to turn the instrument OFF.
6. Sliding Cover. When sliding down the Sliding Cover on the side of the instrument, you will see a Ram Card Slot and a RS-232C Connector. The Ram Card Slot can hold a Ram Card, which provides an external storage space. The RS-232C connector enables you to connect the instrument to an external computer and to the battery charger.

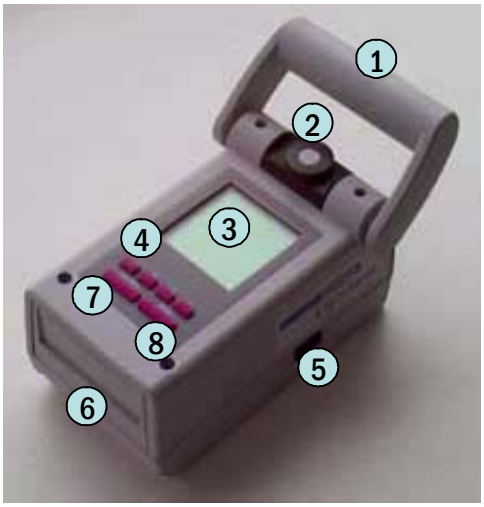


Figure J3. GregTag Macbeth Light Spec.

7. Escape Key. It returns the display to the previous screen or menu. Press this several times to return to the Main Menu.
8. Menu Key. Toggles the Softkeys between menus.

Basic Operation

1. Recharge the battery when the low battery indicator appears in the Display Screen. The battery recharging procedure is described as follows:
2. Turn the instrument Power Switch to the OFF position.
3. Connect the RS-232C Charger-Communications Cable to the Unit.
4. Insert the Charger Pigtail of the RS232C Cable into the charger Cord.
5. Insert the Charger AC plug into an electrical outlet. The battery will automatically begin to recharge.
6. Recharge the battery pack for a minimum of 16 hours.

Taking a measurement

Measurement may be initiated from any of the Measurement Option Screens by pressing the Softkey MEAS in the Screen's Primary function line. When a measurement is initiated, the LightSpex

automatically samples the light level present and adjust its sensitivity automatically to compensate. This process is known as "Auto ranging."

7. If no adjustment is required, the LightSpex will continue to sample the light under test. When complete, the results of this measurement are then displayed. You can toggle through the various Measurement Screens to view the SPD or reduced data calculated from it.
8. Periodically, the unit needs to sample the signal generated by the detector with no light present. This is called the "Dark Rage" or simply the "Dark." When LightSpex requests a dark, a screen will prompt, "PLACE DARK CALIBRATION CAP IN POSITION AND PRESS MENU KEY TO CALIBRATE."
9. Whenever the LightSpex displays this, firmly place the Dust Cap on the Cosine Receptor assembly.
10. Press the MENU key.
11. When complete, the LightSpex will add additional text to the bottom of the Display Screen, "CALIBRATION COMPLETED REMOVE CAP".
12. Press any Softkey to continue.

Save a measurement

Measurement may be saved from any of the Measurement Option Screens by completing the following:

13. Press the Softkey SAVE in the Screen's Primary Function Line.
14. Enter a filename by move the Active cursor to the letter you wish to select using the Softkeys and finish the filename entering by press "FINISHED".
15. The measurement is then stored in the Active Memory under the filename entered.
16. Retrieve the measurement data to a computer using LightSoft software.

J2. ILLUMINANCE MEASUREMENTS

For all of the illuminance measurements the surveyor should choose locations which are representative of the area, not obviously brighter or darker than the surrounding area.

1. Primary work surface, far left: divide the primary work surface into four approximately equal areas, far left, far right, near left and near left, respectively. Choose a location near the center of each area whose illuminance is not obviously darker or brighter than the surrounding area which generally represents this area.
2. Primary work surface, far right
3. Primary work surface, near left
4. Primary work surface, near right
5. Primary work surface, brightest: Move the illuminance meter around on the primary surface to find the brightest spot. If task lighting is used, the brightest spot is generally the center of the task light beam. To make the measurements more meaningful and to minimize the influence from partitions or other barrels, all the measurements should be at least 3 inches from partitions or other barrels because they block light.
6. Primary work surface, darkest: Move the illuminance meter around on the primary surface to find the darkest spot. If task lighting is used, the darkest spot is normally located near the

border of the work surface. To make the measurements more meaningful and to minimize the influence from partitions or other barrels, all measurements should be at least 3 inches from partitions or other barrels because they block light.

7. VDT workstation, source document: Identify where the worker usually puts the source document. The document location is obvious if there is a document holder or a document present. Otherwise, the surveyor should decide the location according to computer setup, keyboard, and any other observations of the workstation. The source document is normally set on the left or right of the keyboard. If a document holder is used, measure the illuminance by putting the illuminance meter on the top of the holder, parallel with the document. If the source document is horizontal on the work surface, measure the horizontal illuminance.
8. VDT workstation, center of VDT screens: Put the illuminance meter on top of the VDT, parallel with the screen. Measure the illuminance near the center.
9. VDT workstation, keyboard: Put the illuminance meter on top of the keyboard and measure the illuminance near its center.
10. Floor: Put the illuminance meter on the floor and measure three locations, which represent geographically the workstation floor area. Record the average value in the space provided in the table.

J3. LUMINANCE MEASUREMENTS

For luminance measurements the surveyor should always sit in the seat at the workstation and face the computer. If no computer is present, face the primary worktable instead. The surveyor should always adjust the luminance meter to the appropriate focus before taking measurements.

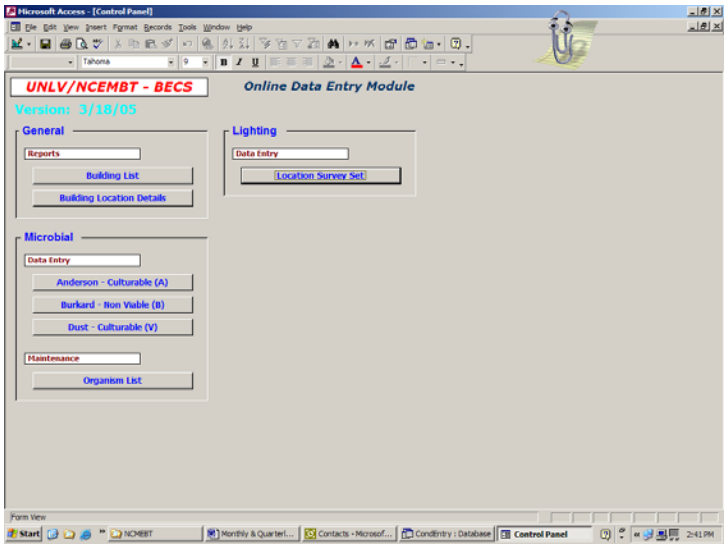
11. Ceiling between luminaries: The surveyor should measure from a spot on the ceiling between luminaires, which is near the middle of two luminaires. It can be most easily seen from the normal sitting position.
12. Brightest light source in field of view: The surveyor should measure the brightest spot from the light source in the field of view, which can be seen from the normal sitting position with eyes horizontal. The field of view here is defined as 120° vertically and 160° horizontally to the eyes.
13. Brightest ceiling area in field of view: The surveyor should measure the brightest spot of ceiling area in the field of view, which can be seen from the normal sitting position. In indirect or direct/indirect lighting systems, the brightest ceiling area is generally located right above luminaires. For a location with daylighting, the brightest ceiling area is generally located at the place where daylight has the greatest input. When the brightest area is not obvious, the surveyor should take several measurements and choose the brightest one among them.
14. Darkest walls or partition area in field of view. The surveyor should measure the darkest walls or partition area in the field of view, which can be seen from the normal sitting position. The surveyor should not choose the darkest area that is very small, such as a black plastic edge of a partition or a small area of shadow caused by a hanging telephone bookshelf, because the very small area does not have significant influence on the entire field of view. As a rule in this study, the area should be more than 0.25 m2 (2.7 ft2), which corresponds to 5% of field of view when viewed at the distance of 1 m (3.3 ft).

15. Wall or partition area, straight ahead: The surveyor should measure the representative location of the wall or partition area straight ahead, at eye level, when seated at normal sitting position.
16. Wall or partition area, 90° to the right
17. Wall or partition area, 90° to the right
18. Brightest area of the sky from the window: The surveyor should move close to the nearest window and measure the brightest area of the sky from the window. If the workstation is windowless, the surveyor does not need to take this measurement. As windowless workstation exists when: 1) the worker does not have a direct view to windows when normally seated in the workstation; 2) there are more than 6 m (20ft) from worker's seat to the nearest window; or 3) the worker has a direct view to windows but there is more than 10 m (33ft) to the nearest window.
19. A nearby building from the window. Measure the brightest spot of a nearby building. The surveyor should not take this measurement if the workstation is windowless or there is no building or construction in the field of view through the window.
20. Floor: Measure three locations on the floor which represent geographically the workstation floor area. Record the average value in the space provided in the table.
21. The last section of the table records luminances of room surfaces and window surfaces. The surveyor divides each surface approximately into 15 pieces of equal area, five horizontally by three vertically. The lighting surveyor then takes the luminance of a representative point of each area, located near the center of each area. This last section of data was not collected for the first six office buildings because this was not included in the original measurement protocols. We added this data because we realized later in the project that it might provide important information to the building lighting environment.

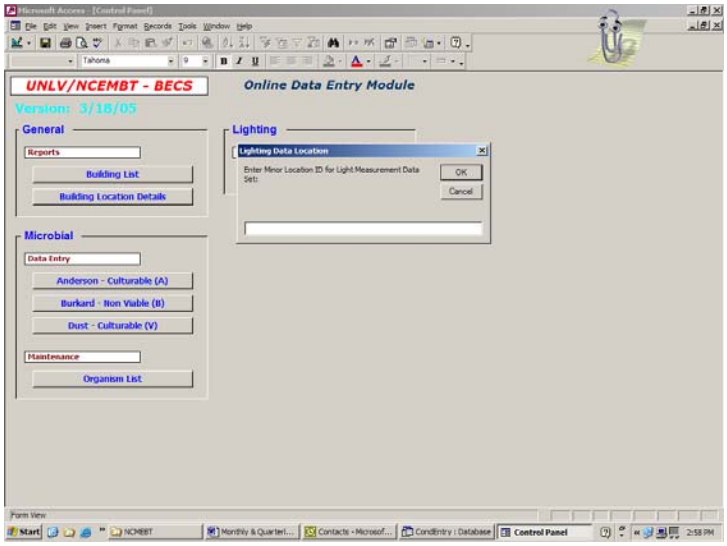
J4. LIGHTING DATA ENTRY PROCEDURE

The lighting data are entered manually into the database. The procedure is described as below:

6. Start the Online Data Entry Module by opening the file, "CondEntry.adp." Then the following screen will appear:



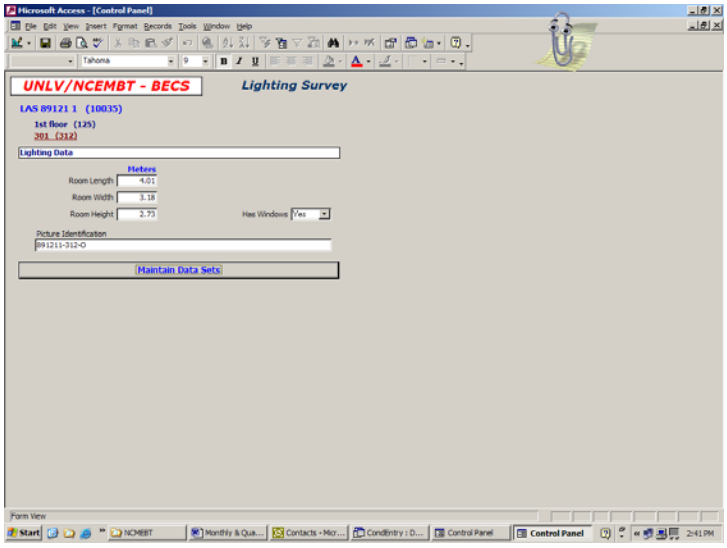
7. Click on “Location Survey Set” button under the Lighting Section. A “Lighting Data Location” window props up to ask you to “Enter Minor Location ID for Light Measurement Data Set”, shown as below:



8.

9.

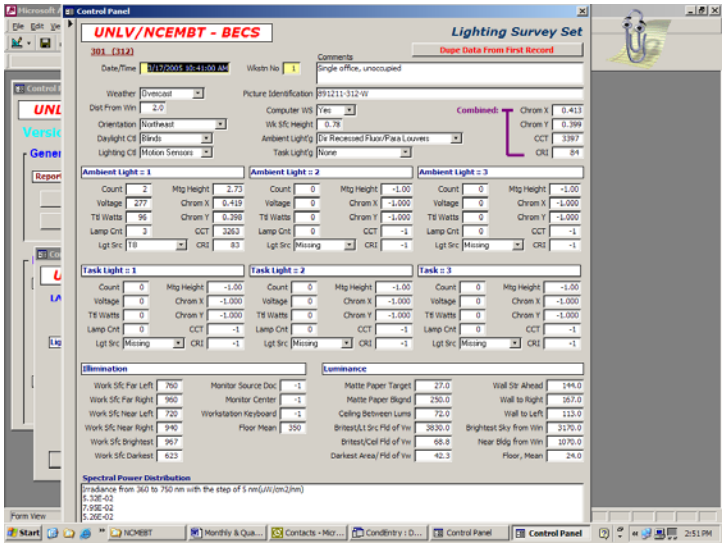
10. After entering the Minor Location ID, which you may get from the database administrator, you will get the following screen:



11.

12.

13. Enter the required information, and then click “Maintain Data Sets” bar at the bottom of the screen. Then you enter the following screen:



Input the information as recorded in the lighting field survey form. The above screen is an example from one of the building monitoring events.

APPENDIX K: LIGHTING FIELD SURVEY TABLE

K1. ROOM DESCRIPTIONS

Table K1. Template used to list the general characteristics of each location (zone) in which lighting measurements were collected.

City, building, room	
Area of the room (m^2)	
Room height (m)	
Work surface height (m)	
Windows availability (Circle one that applies)	yes/no
Daylighting control means (Circle all that applies)	blinds/shades/overhang/shelf/none/others
Whether have computers (Circle one that applies)	Yes/no
Notes and comments	

K2. LIGHTING CONTROL SYSTEM TYPES

Table K2. Template used to describe the type of lighting components at each location (zone).

Lighting control methods (circle all that apply): ▪ Manual ▪ Timing devices ▪ Photo sensors ▪ Occupancy sensors ▪ Others
Type of ambient lighting system (circle one that applies): ▪ Direct recessed fluorescent with parabolic louvers ▪ Direct recessed fluorescent with prismatic lens ▪ Direct fluorescent surface mounted with egg grate ▪ Indirect fluorescent furniture integrated ▪ Indirect fluorescent pendant mounted ▪ Direct/indirect fluorescent pendant mounted ▪ Indirect metal halide HID pendant mounted ▪ Other configurations
Type of task lighting (circle one that applies): ▪ No task units ▪ Furniture integrated units ▪ Desk movable units ▪ Others

K3. LUMINARY INFORMATION

K3.1 Ambient Light 1

Table K3. Template used to characterize the primary ambient lighting device(s) at each location (zone).

Numbers of luminaries in the room	
Voltage (V)	
Total wattages (W)	
Numbers of lamps in a luminaire	
Light source	T12/T8/T5/CFL/Incandescent/Metal Halide/others
Mounting height (m)	
Chromaticity (x, y)	
CCT (K)	
CRI	
File name for the SPD	

K3.2 Ambient Light 2

Table K4. Template used to characterize secondary ambient lighting device(s) at each location (zone); only to be used if secondary ambient lights are used in the zone.

Numbers of luminaries in the room	
Voltage (V)	
Total wattages (W)	
Numbers of lamps in a luminaire	
Light source	T12/T8/T5/CFL/Incandescent/Metal Halide/others
Mounting height (m)	
Chromaticity (x, y)	
CCT (K)	
CRI	
File name for the SPD	

K3.3 Ambient Light 3

Table K5. Template used to characterize additional ambient lighting device(s) at each location (zone); only to be used if additional ambient lights are used in the zone.

Numbers of luminaries in the room	
Voltage (V)	
Total wattages (W)	
Numbers of lamps in a luminaire	
Light source	T12/T8/T5/CFL/Incandescent/Metal Halide/others
Mounting height (m)	
Chromaticity (x, y)	
CCT (K)	
CRI	
File name for the SPD	

K3.4 Task Light 1

Table K6. Template used to characterize the primary task lighting device(s) at each location (zone); only to be used if task lights are used in the zone.

Numbers of luminaries in a workstation	
Voltage (V)	
Total wattages (W)	
Numbers of lamps in a luminaire	
Light source	T12/T8/T5/CFL/Incandescent/Metal Halide/others
Work surface height (m) for workstation	
Chromaticity (x, y)	
CCT (K)	
CRI	
File name for the SPD	

K3.5 Task Light 2

Table K7. Template used to characterize secondary task lighting device(s) at each location (zone); only to be used if secondary task lights are used in the zone.

Numbers of luminaries in a workstation	
Voltage (V)	
Total wattages (W)	
Numbers of lamps in a luminaire	
Light source	T12/T8/T5/CFL/Incandescent/Metal Halide/others
Work surface height (m) for workstation	
Chromaticity (x, y)	
CCT (K)	
CRI	
File name for the SPD	

K3.6 Task Light 3

Table K8. Template used to characterize additional task lighting device(s) at each location (zone); only to be used if additional task lights are used in the zone.

Numbers of luminaries in a workstation	
Voltage (V)	
Total wattages (W)	
Numbers of lamps in a luminaire	
Light source	T12/T8/T5/CFL/Incandescent/Metal Halide/others
Work surface height (m) for workstation	
Chromaticity (x, y)	
CCT (K)	
CRI	
File name for the SPD	

K4. LIGHT POWER DENSITY

Table K9. Template used to describe the light power density.

LPD for the building (w/m^2):	
Write down how to obtain the LPD here:	

K5. MEASUREMENTS OF WORKSTATIONS

K5.1 General Information

Table K10. Templates used to describe general information at each zone's workstation(s).

Location ID				
Date				
Time				
Window availability (Yes/No)				
Window orientation (North/ Northeast/ East / Southeast/ South/ Southwest/ West/ Northwest)				
Distance to nearest window				
Weather (clear/partly cloudy/overcast)				
Note				

K5.2 Illuminance Measurements

K11. Template used to record the illuminance measurements at each zone's workstation(s).

(1). Primary work surface, far left	Lux			
(2). Primary work surface, far right	Lux			
(3). Primary work surface, near left	Lux			
(4). Primary work surface, near right	Lux			
(5). Primary work surface, brightest	Lux			
(6). Primary work surface, darkest	Lux			
(7). VDT workstation, source document	Lux			
(8). VDT workstation, center of VDT screen	Lux			
(9). VDT workstation, keyboard	Lux			
(10). Floor (average over 3 measurements on the floor of the workstation)	Lux			

K5.3 Luminance Measurements

K12. Template used to record the luminance measurements at each zone's workstation(s).

(11). Ceiling between luminaries	cd/m^2			
(12). Brightest light source in field of view	cd/m^2			
(13). Brightest ceiling area in field of view	cd/m^2			
(14). Darkest walls or partition area in field of view	cd/m^2			
(15). Wall or partition area straight ahead	cd/m^2			
(16). Wall or partition area 90 deg. to the right	cd/m^2			
(17). Wall or partition area 90 deg. to the left	cd/m^2			
(18). Brightest area of the sky from the window	cd/m^2			
(19). A nearby building from the window	cd/m^2			
(20). Floor (average over 3 measurements on the floor of the workstation)	cd/m^2			

K5.4 Color Measurements

K5.4.1 Color of the lighting at work surface

Table K13. Template used to record the color of the lighting at the work surface at each zone.

Chromaticity (x,y)				
CCT	K			
CRI				
File name for the SPD				

K5.4.2 Color of the lighting at other places

Table K14. Template used to record the color of the lighting at other locations at each zone.

Chromaticity (x,y)				
CCT	K			
CRI				
File name for the SPD				
Note (locations of the measurement)				

APPENDIX L- ENERGY USAGE

Table L1. Energy Usage for the Ten Monitored Buildings.

Building ID	Gross Square Footage	Time Period[1]	Electric Energy Consumed in kWh	Cost of Electric Energy Consumed	Natural Gas Consumed in therm	Cost of Natural Gas Consumed
1	40,650	Jan - Dec. 2004	1,044,695	Unknown[2]	7,079	$6,102
2	107,000	Jan – Dec. 2004	2,304,621	Unknown	31,675	$24,154
3	229,000	Jan – Dec. 2004	7,988,258	Unknown	29,132	$22,763
4	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown
5	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown
6	189,500	Jan. – Dec. 2004	2,003,040	$158,547	Unknown	Unknown
7	180,000	Oct. 2003 - Sept. 2005	5,559,900	$752,191	103,595	$14,787
8	52,300	Jan. – Aug. 2005	371,040	$45,186	1,460	$1,796
		Jan. - July 2004	245,600 0	$34,047	2,405	$2,602
		Sept. – Nov. 2003	177,280	$22,782	1,101	$1,316
9	110,000	Unknown	Unknown	Unknown	Unknown	Unknown
10	52,000	Jan. - Dec. 2005	751,428	$121,432	231,120	

Notes:

1. Time period for which consumption of both electric enegy and natural gas was reported
2. Unknown marks a field for which no data could be obtained from the building operator

APPENDIX M: IEQ RESULTS

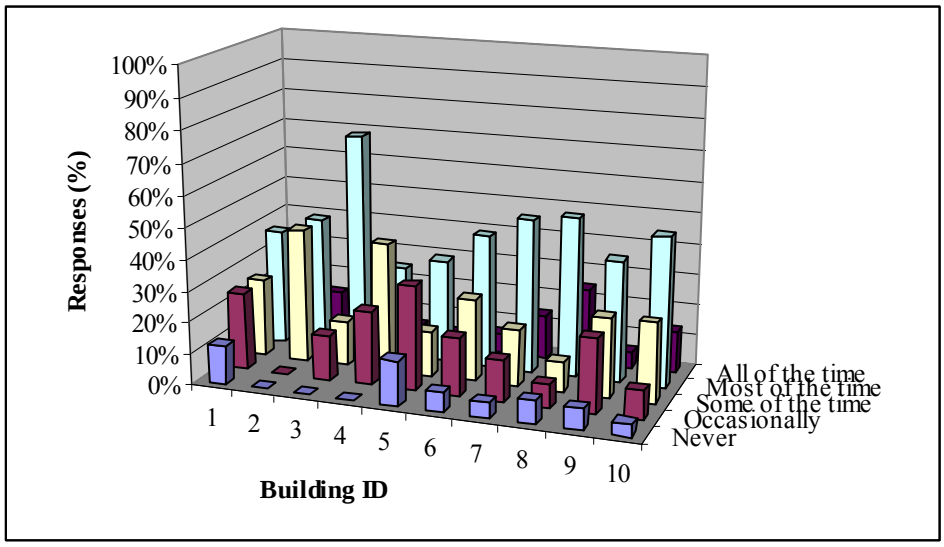


Figure M1. Summary of occupants' responses on the perception questionnaire when asked how often they would rate the acceptability of the temperature in their work area.

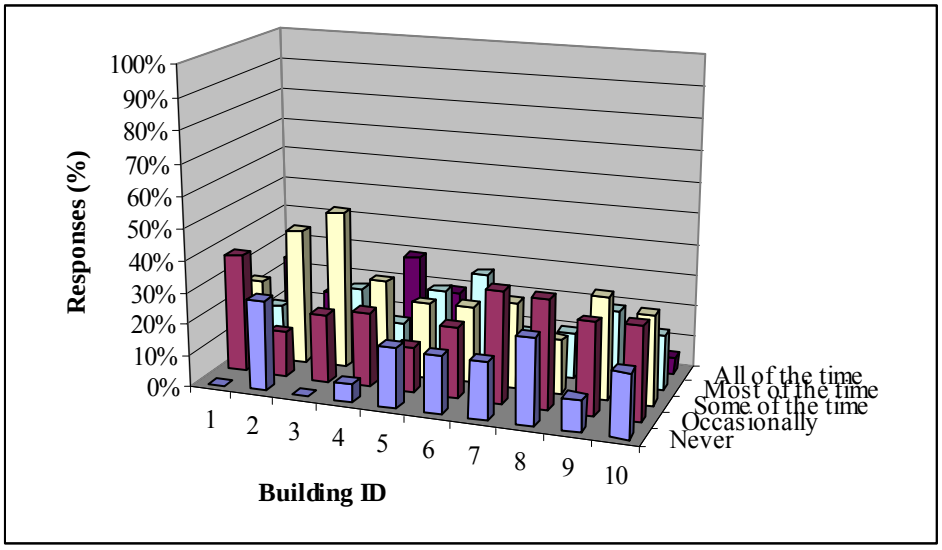


Figure M2. Summary of occupants' responses on the perception questionnaire when asked how often the temperature in their work area fluctuates throughout the course of an entire work day.

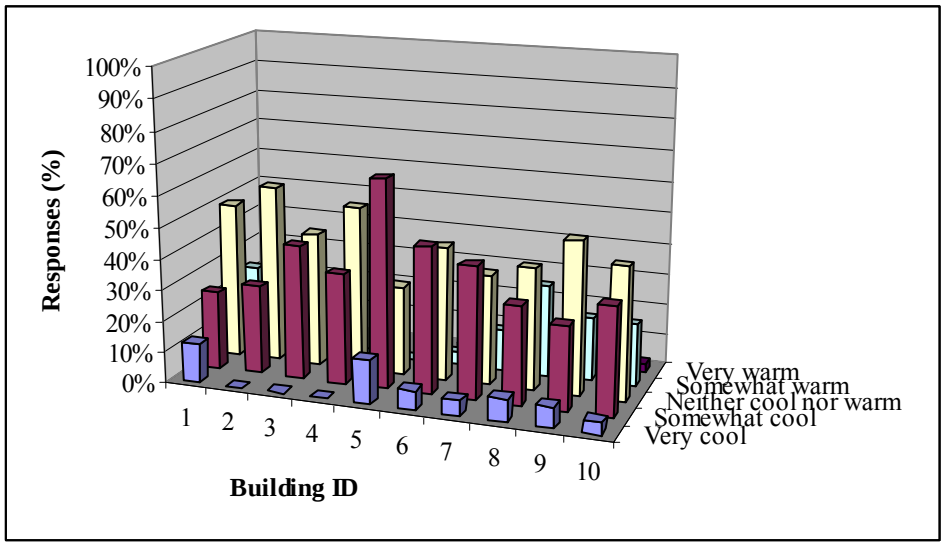


Figure M3. Summary of occupants' responses on the perception questionnaire when asked the temperature in their work area when they are the most comfortable.

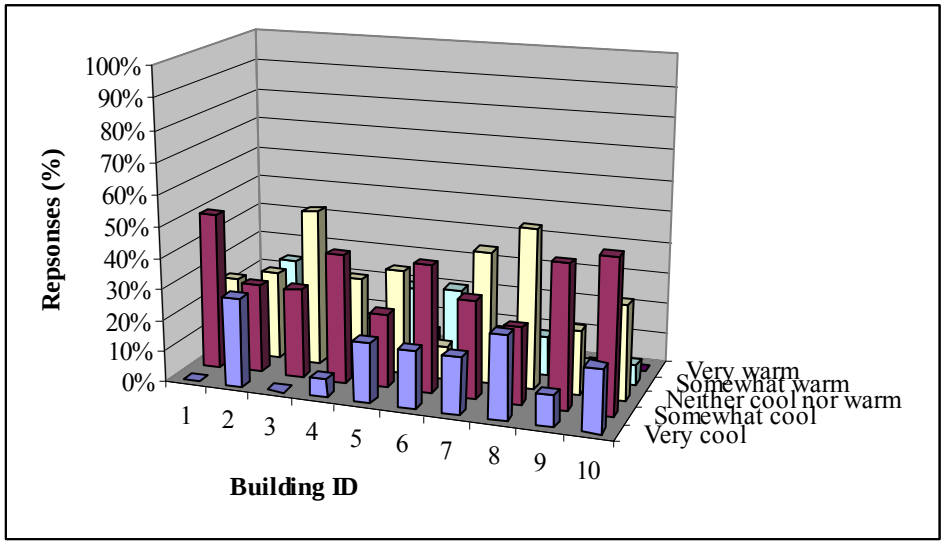


Figure M4. Summary of occupants' responses on the perception questionnaire when asked the temperature in their work area throughout the mornings.

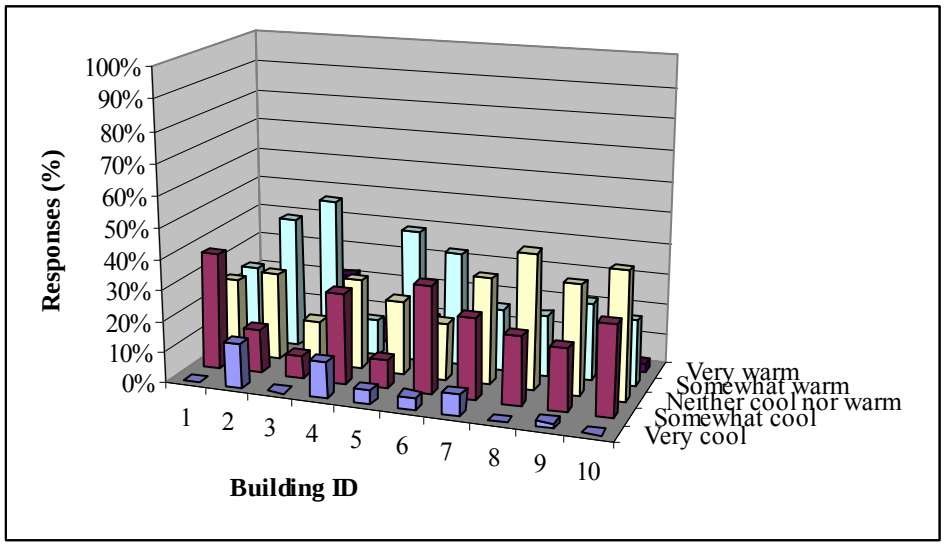


Figure M5. Summary of occupants' responses on the perception questionnaire when asked the temperature in their work area throughout the afternoons.

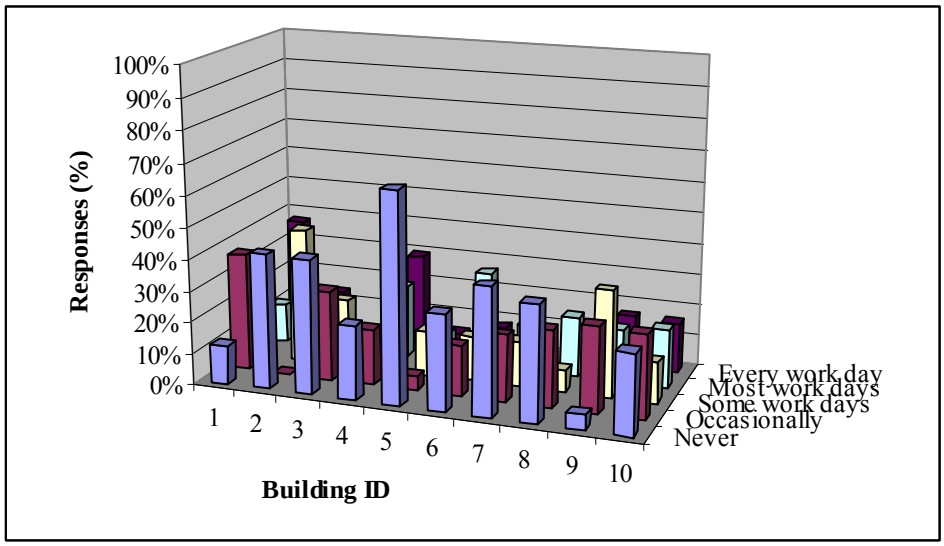


Figure M6. Summary of occupants' responses on the perception questionnaire when asked how often the temperature in their work area has been too cool.

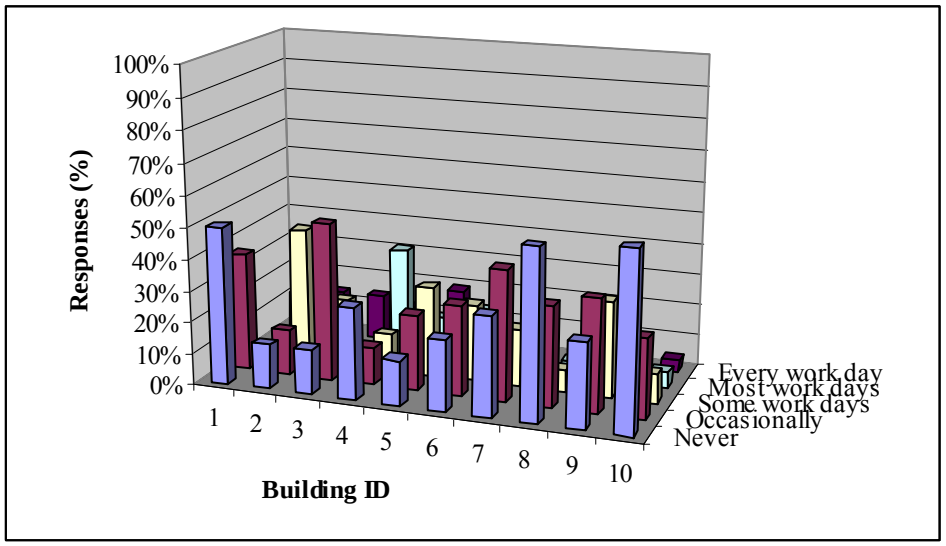


Figure M7. Summary of occupants' responses on the perception questionnaire when asked how often the temperature in their work area has been too warm.

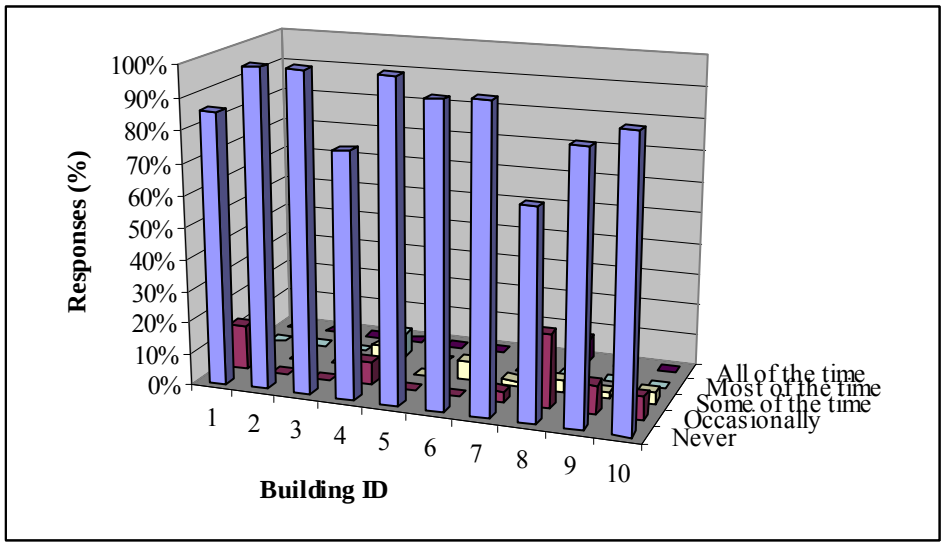


Figure M8. Summary of occupants' responses on the perception questionnaire when asked how often they adjust the thermosat in their work area when the temperature is too cool.

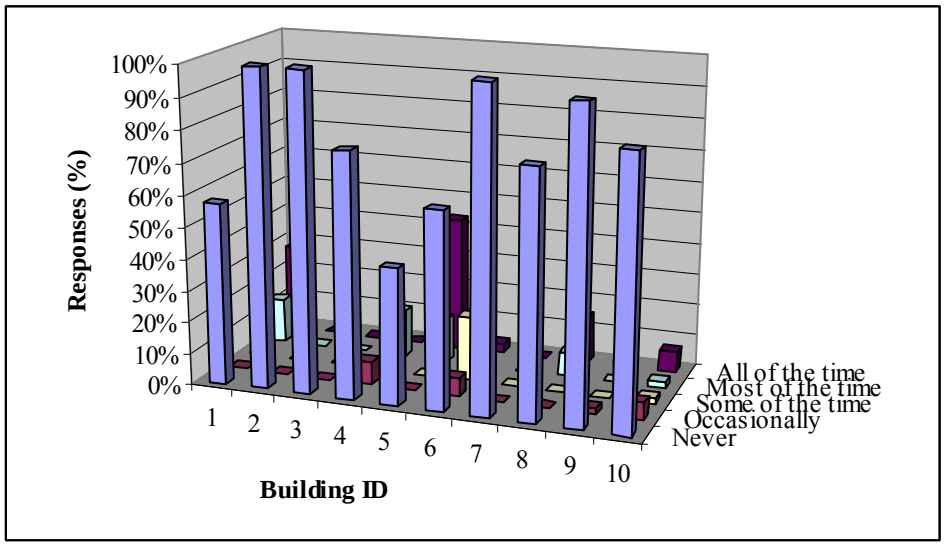


Figure M9. Summary of occupants' responses on the perception questionnaire when asked how often they use a personal space heater when the temperature in their work area is too cool.

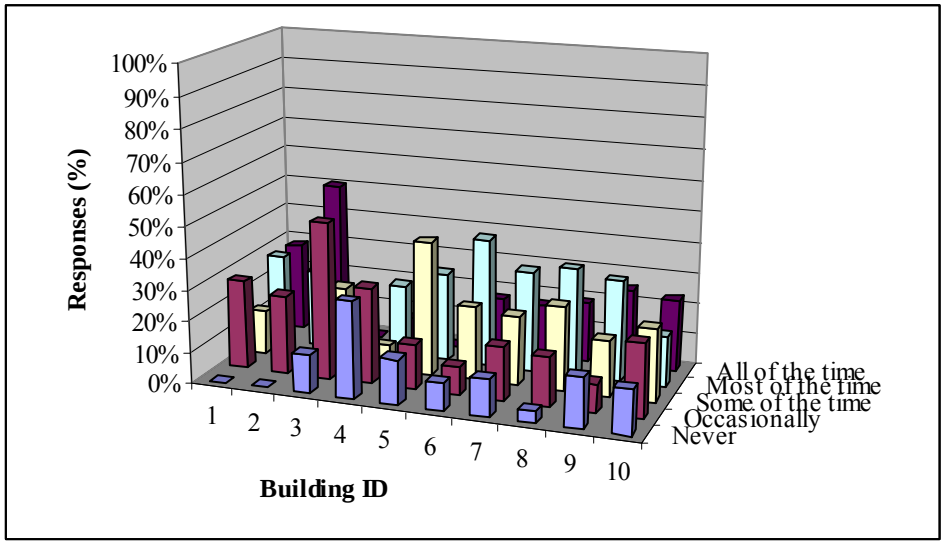


Figure M10. Summary of occupants' responses on the perception questionnaire when asked how often they wear warmer clothes when the temperature in their work area is too cool.

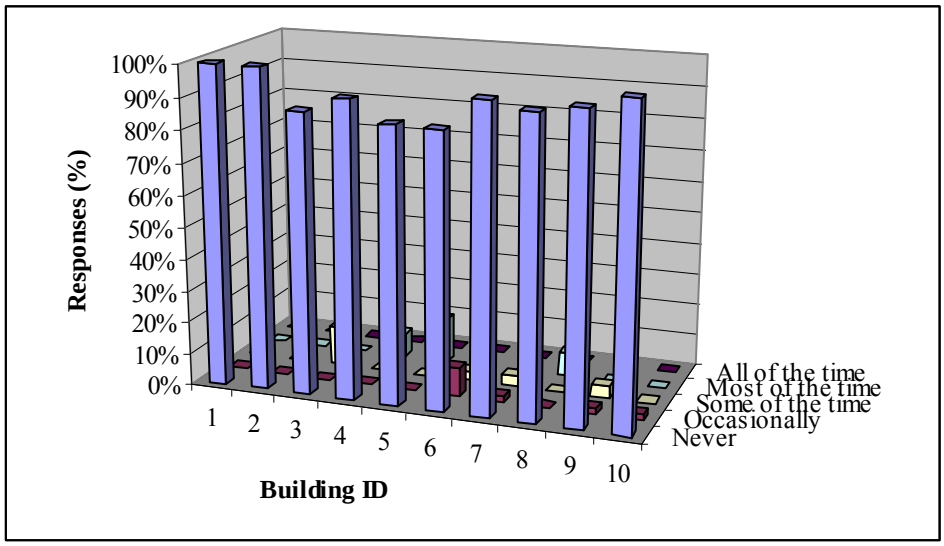


Figure M11. Summary of occupants' responses on the perception questionnaire when asked how often they open/close a door when the temperature in their work area is too cool.

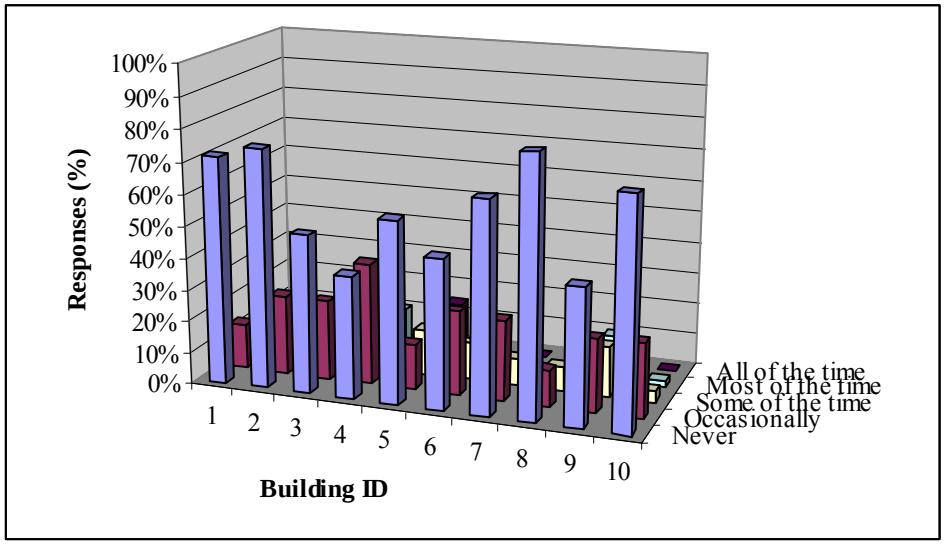


Figure M12. Summary of occupants' responses on the perception questionnaire when asked how often they report to management or facilities personnel when the temperature in their work area is too cool.

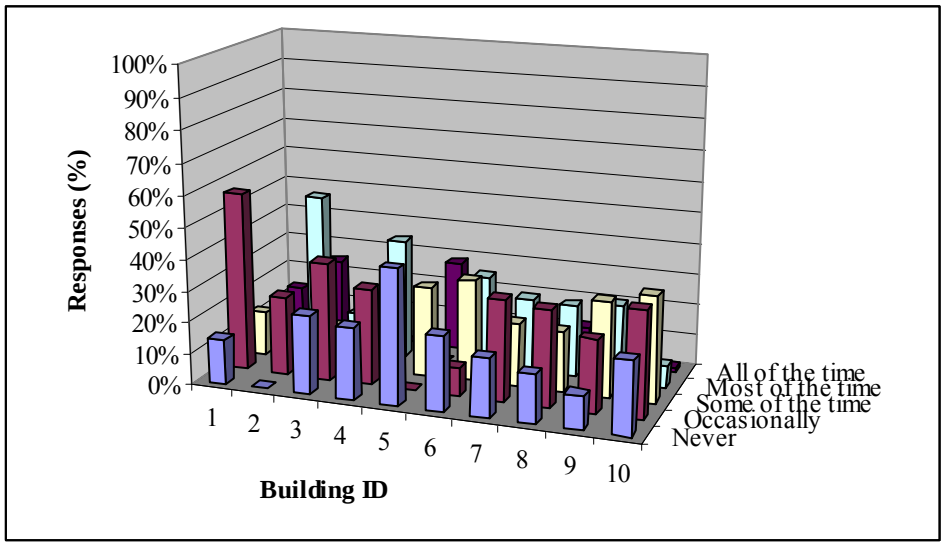


Figure M13. Summary of occupants' responses on the perception questionnaire when asked how often they mention to their co-workers when the temperature in their work area is too cool.

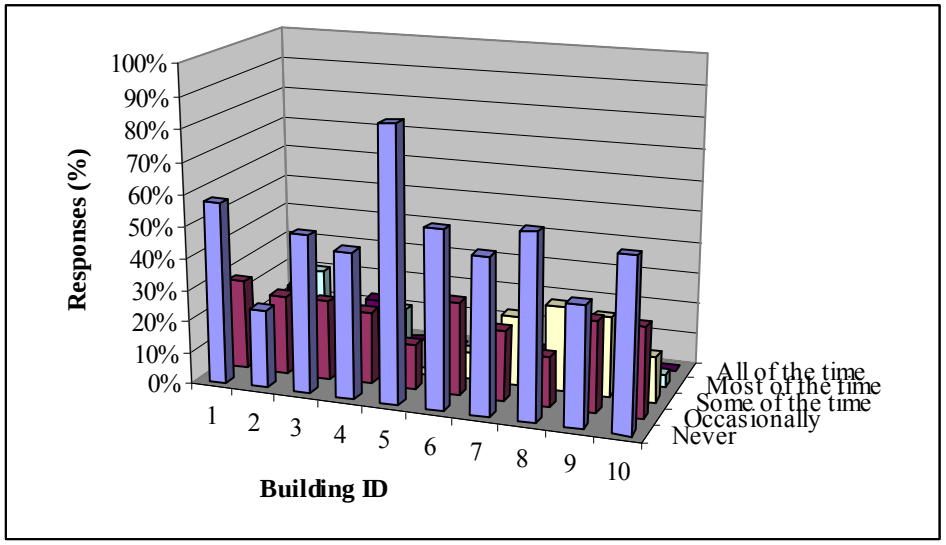


Figure M14. Summary of occupants' responses on the perception questionnaire when asked how often they temporarily leave their work area when the temperature is too cool.

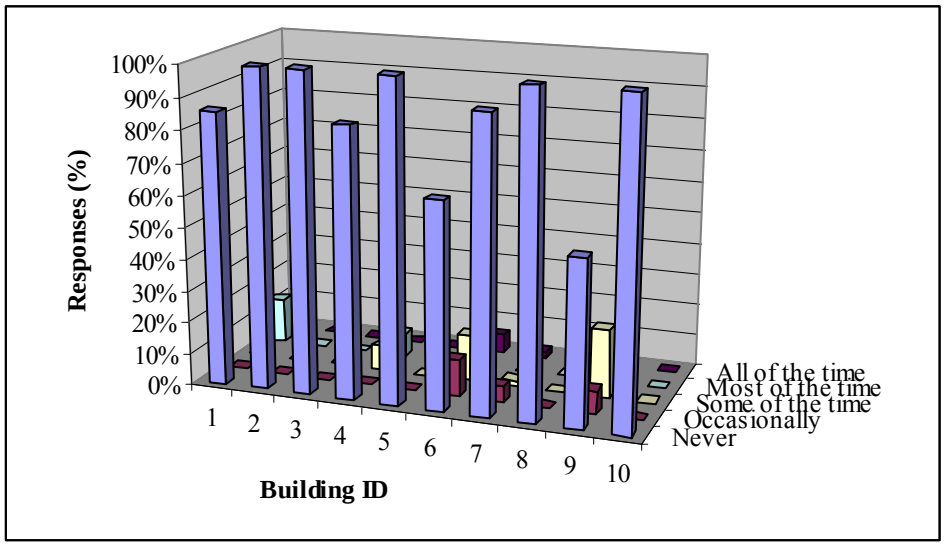


Figure M15. Summary of occupants' responses on the perception questionnaire when asked how often they block or unblock air supply registers when the temperature in their work area is too cool.

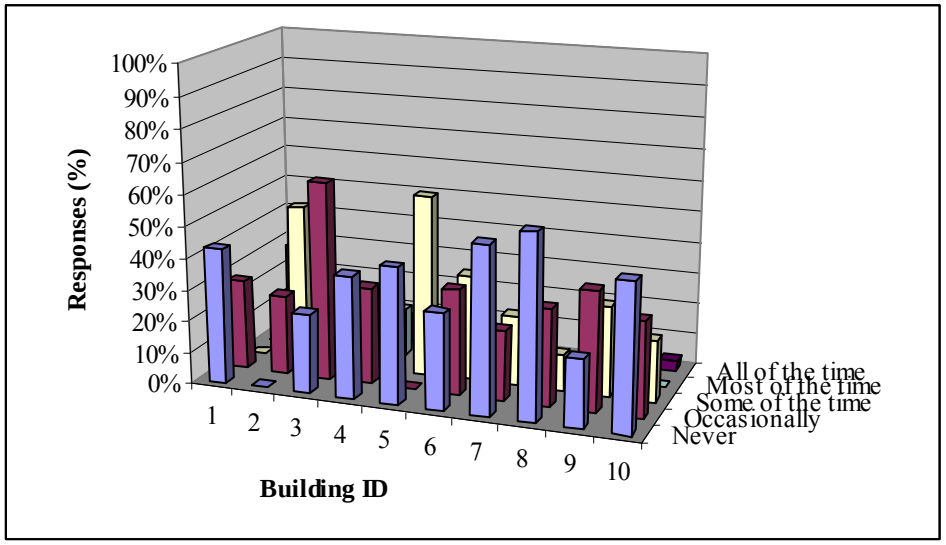


Figure M16. Summary of occupants' responses on the perception questionnaire when asked how often their productivity is affected when the temperature in their work area is too cool.

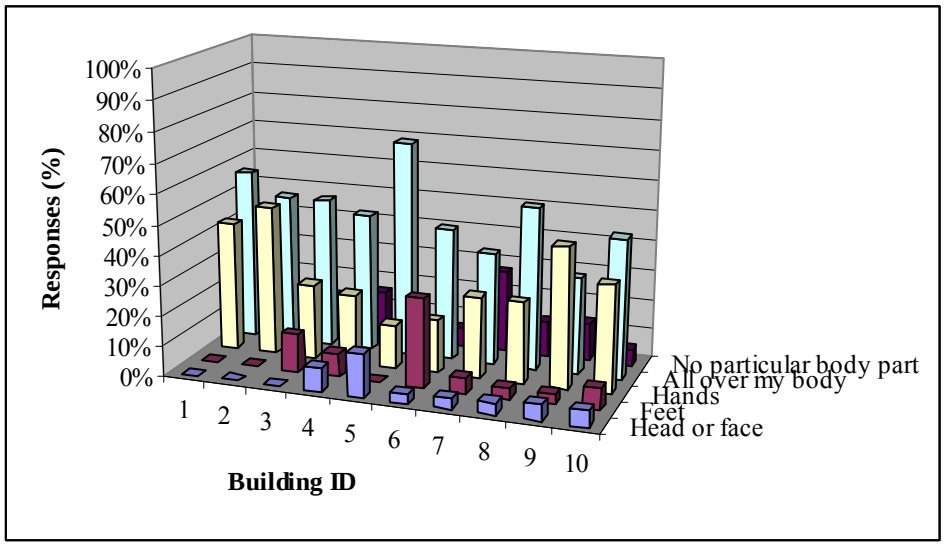


Figure M17. Summary of occupants' responses on the perception questionnaire when asked where they feel it the most when the temperature in their work area is too cool.

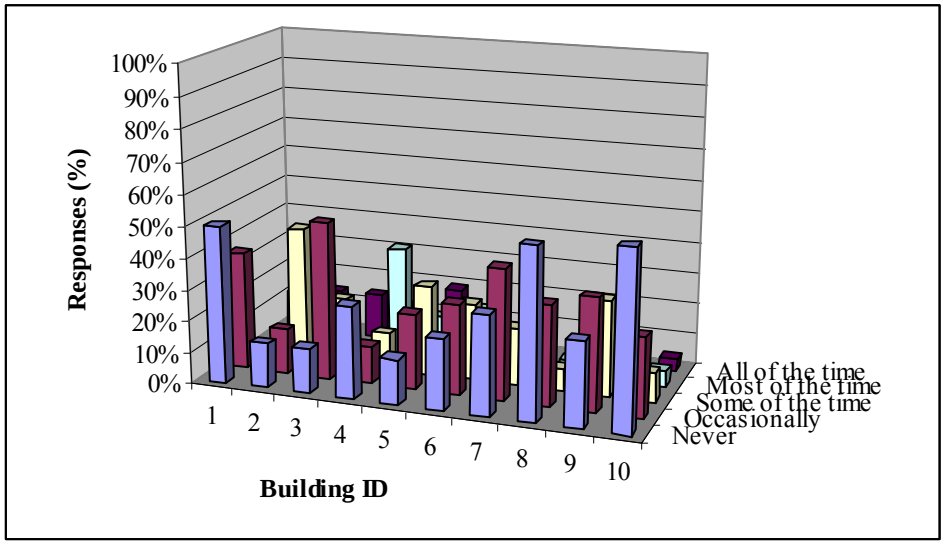


Figure M18. Summary of occupants' responses on the perception questionnaire when asked how often they adjust the thermostat when the temperature in their work area is too warm.

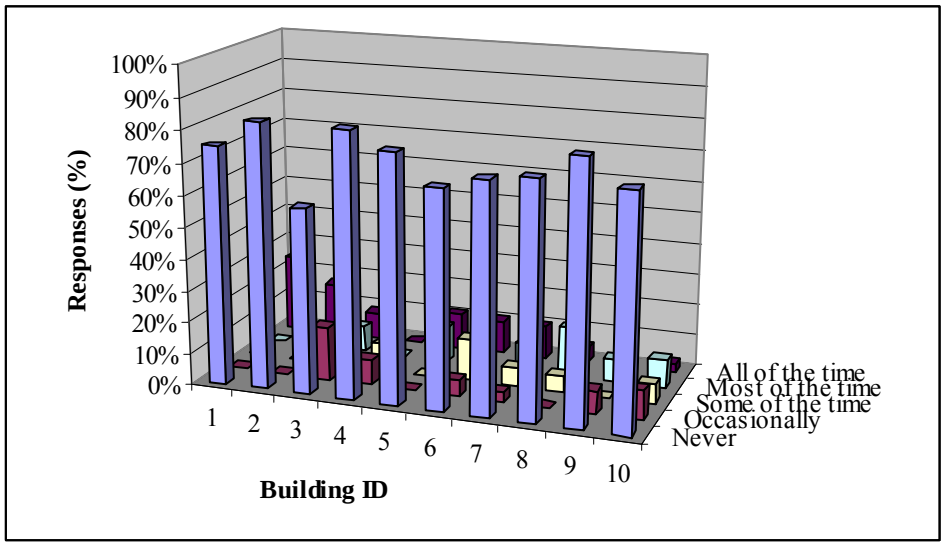


Figure M19. Summary of occupants' responses on the perception questionnaire when asked how often they use a personal fan when the temperature in their work area is too warm.

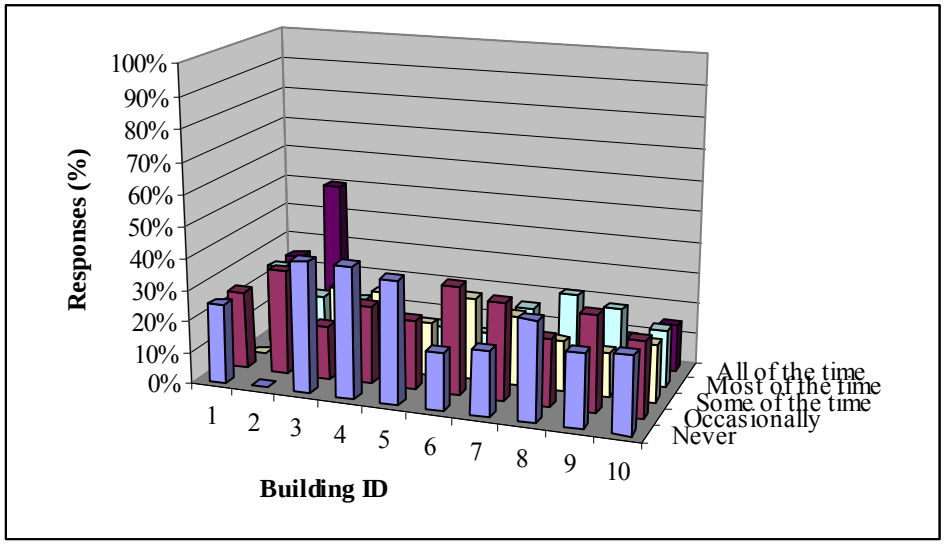


Figure M20. Summary of occupants' responses on the perception questionnaire when asked how often they wear lighter clothing or remove clothing when the temperature in their work area is too warm.

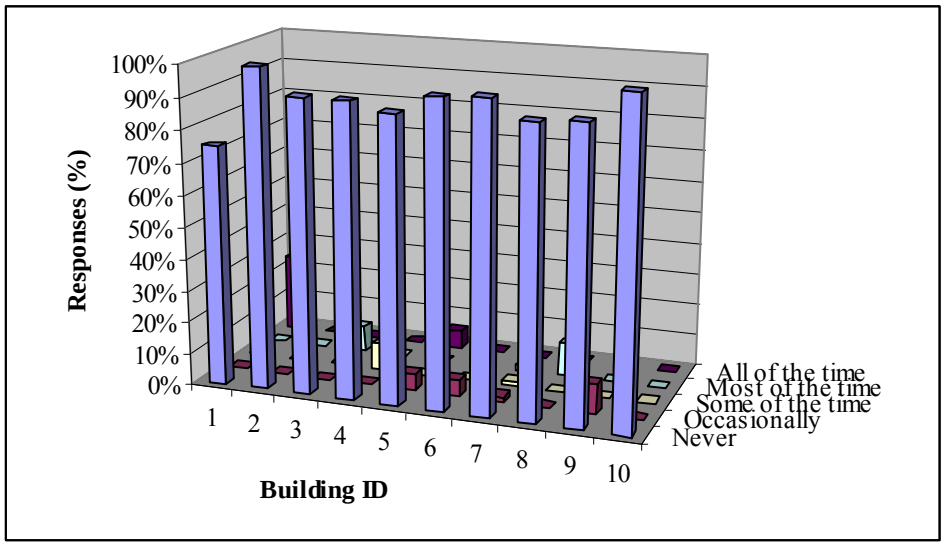


Figure M21. Summary of occupants' responses on the perception questionnaire when asked how often they open/close a door when the temperature in their work area is too warm.

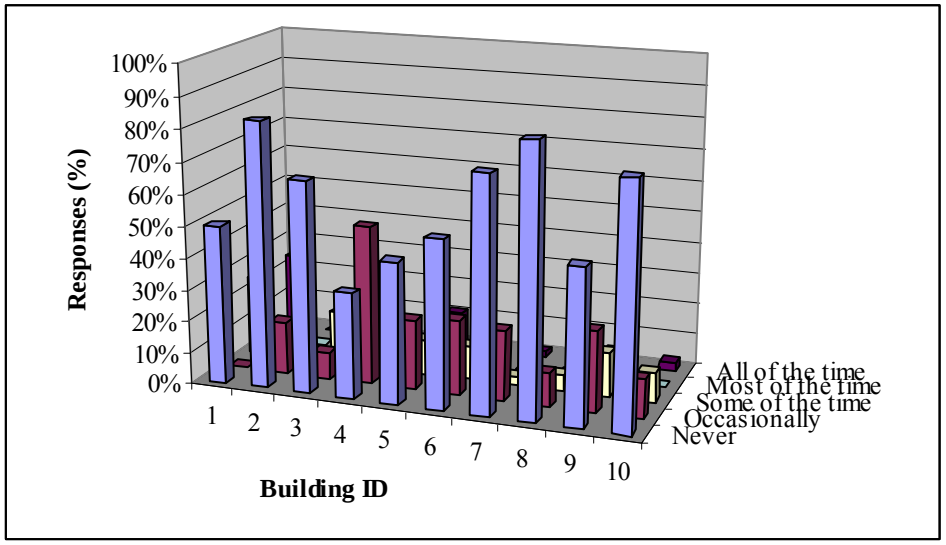


Figure M22. Summary of occupants' responses on the perception questionnaire when asked how often they report to management or facilities personnel when the temperature in their work area is too warm.

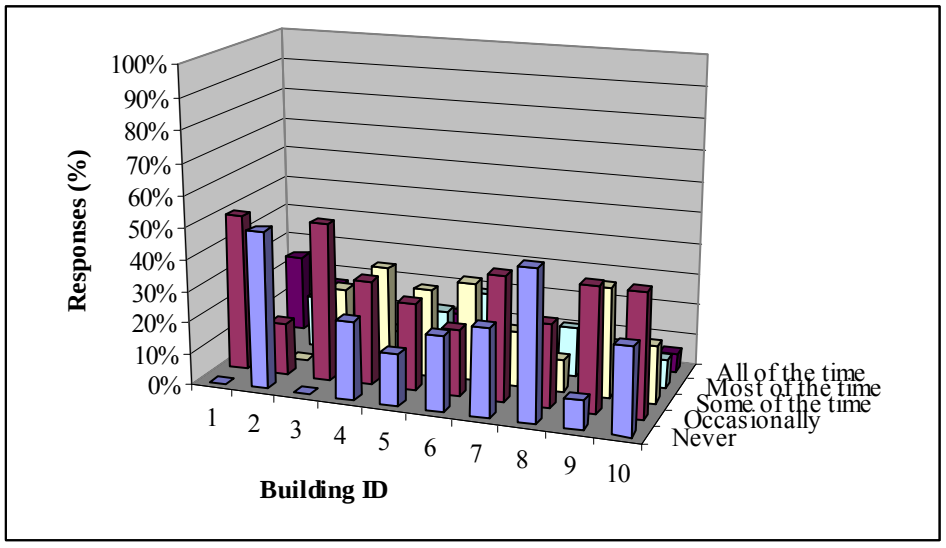


Figure M23. Summary of occupants' responses on the perception questionnaire when asked how often they mention to their co-workers when the temperature in their work area is too warm.

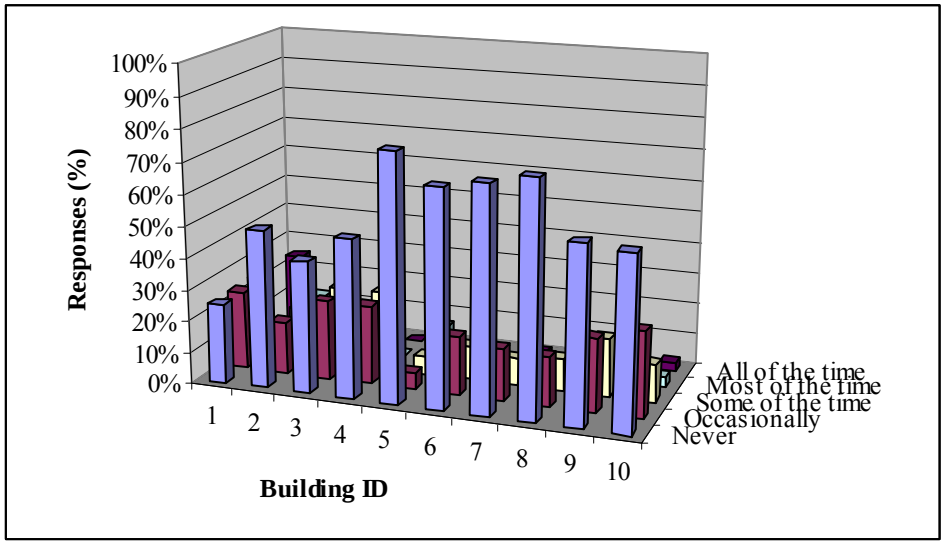


Figure M24. Summary of occupants' responses on the perception questionnaire when asked how often they temporarily leave their work area when the temperature in their work area is too warm.

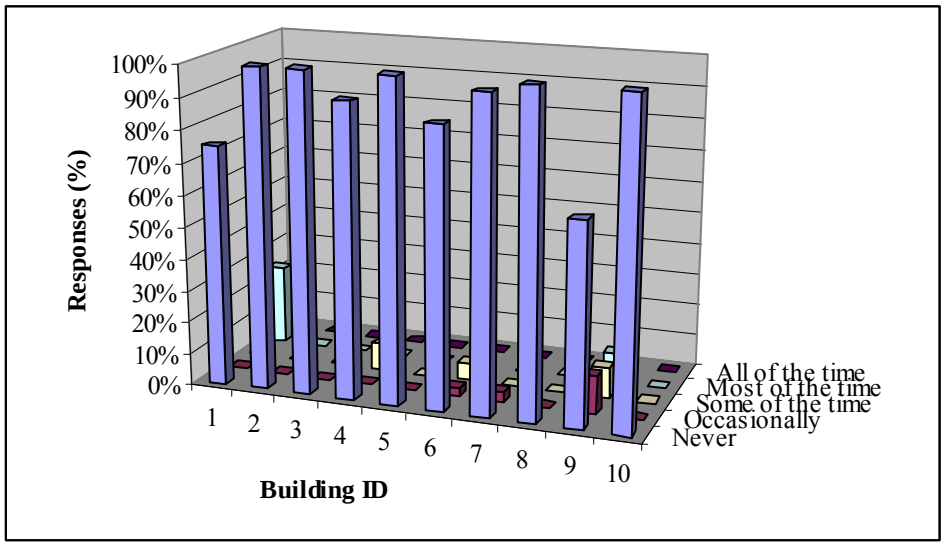


Figure M25. Summary of occupants' responses on the perception questionnaire when asked how often they block or unblock air supply registers when the temperature in their work area is too warm.

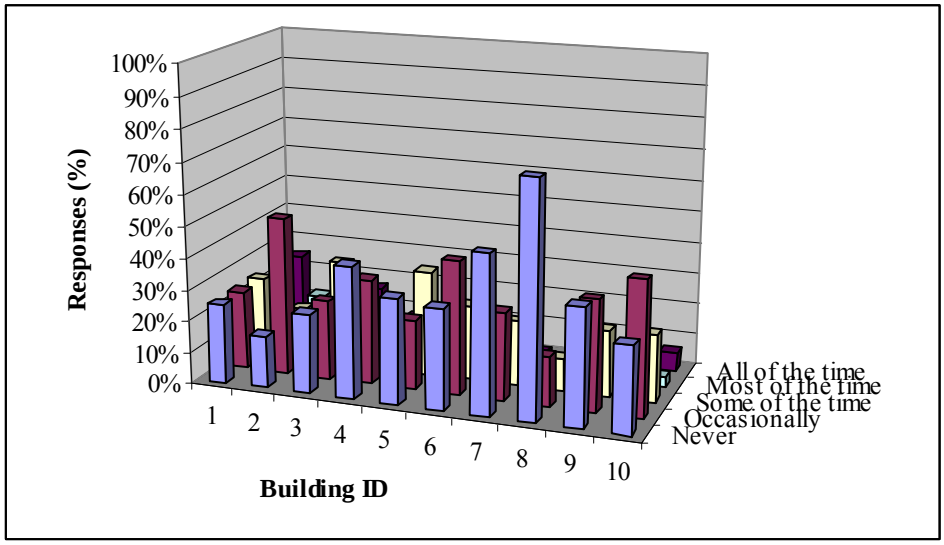


Figure M26. Summary of occupants' responses on the perception questionnaire when asked how often their productivity is adversely affected when the temperature in their work area is too warm.

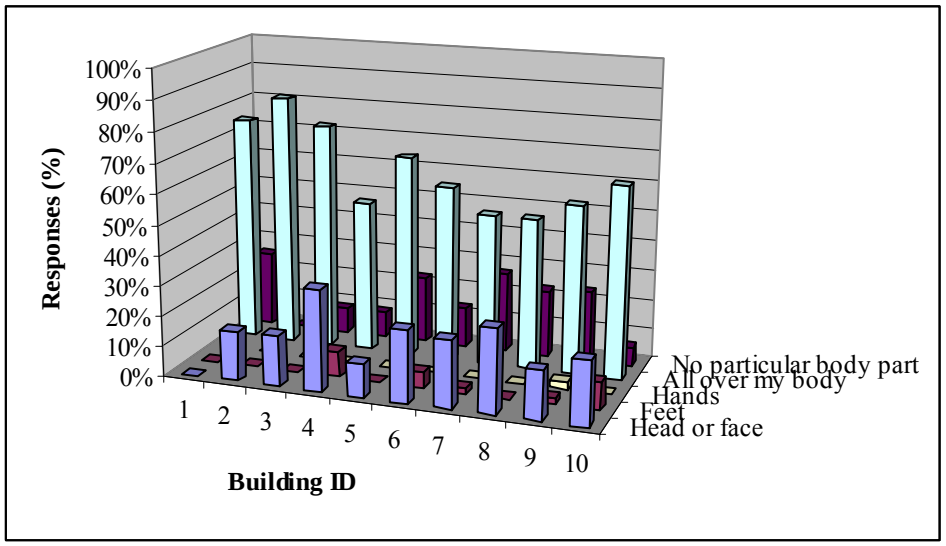


Figure M27. Summary of occupants' responses on the perception questionnaire when asked where they feel it most when the temperature in their work area is too warm.

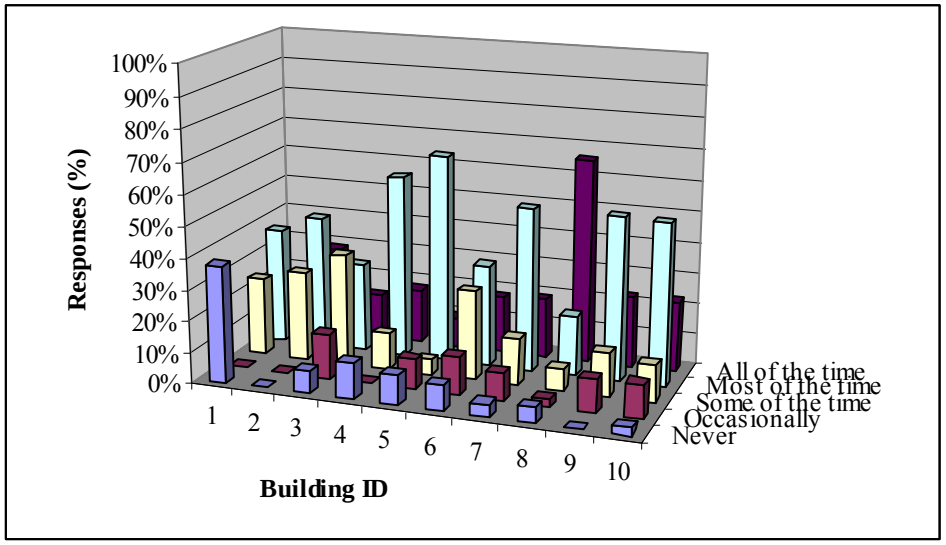


Figure M28. Summary of occupants' responses on the perception questionnaire when asked how often the humidity in their work area throughout the course of an entire work day is acceptable.

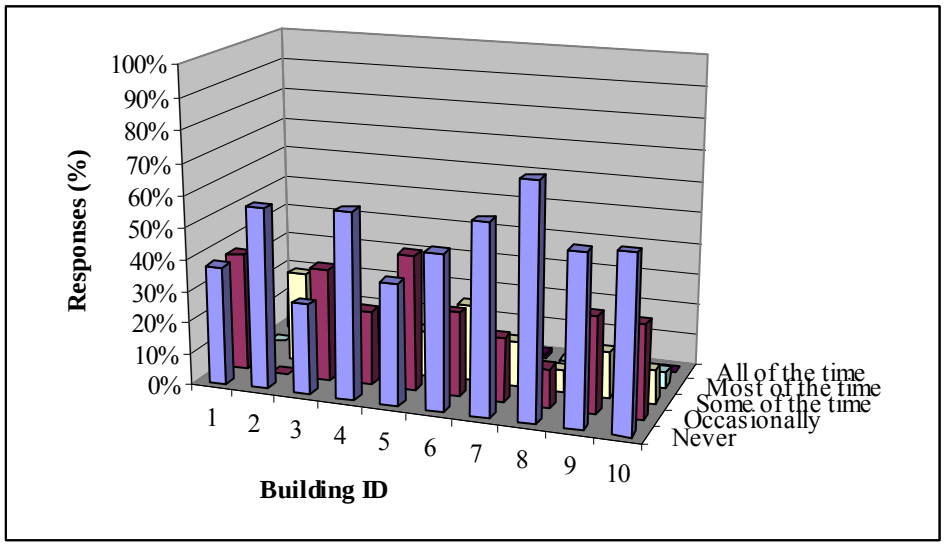


Figure M29. Summary of occupants' responses on the perception questionnaire when asked how often the humidity fluctuates in their work area during the course of an entire work day.

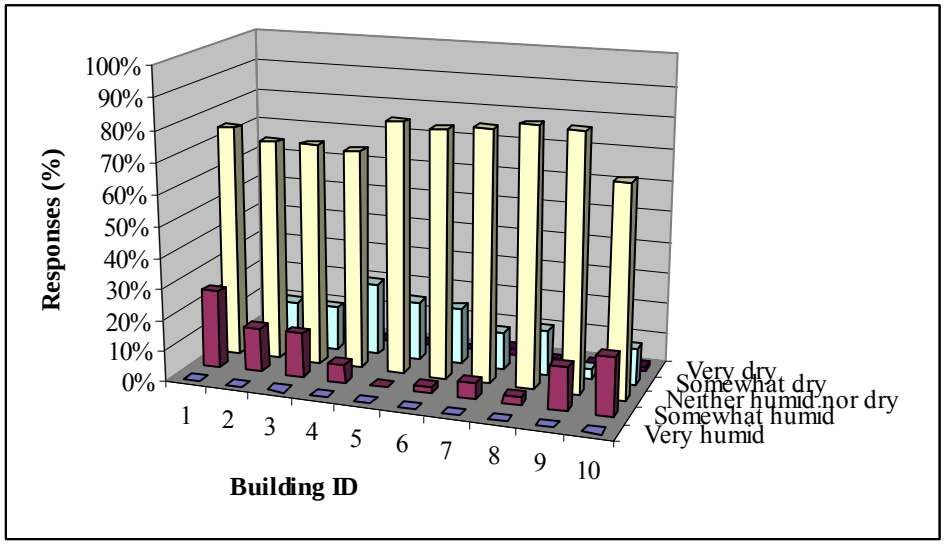


Figure M30. Summary of occupants' responses on the perception questionnaire when asked the humidity in their work area when they are the most comfortable.

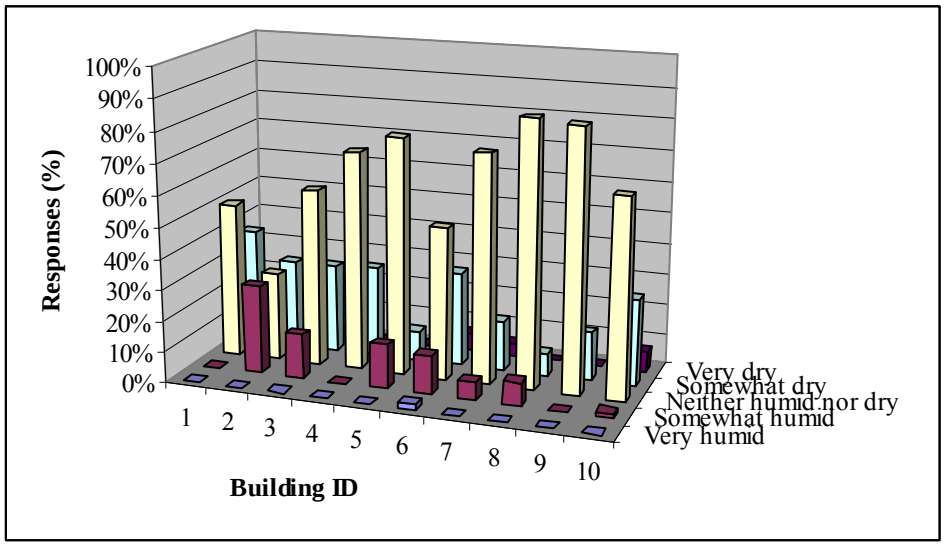


Figure M31. Summary of occupants' responses on the perception questionnaire when asked how humid the air in their work area is throughout the mornings.

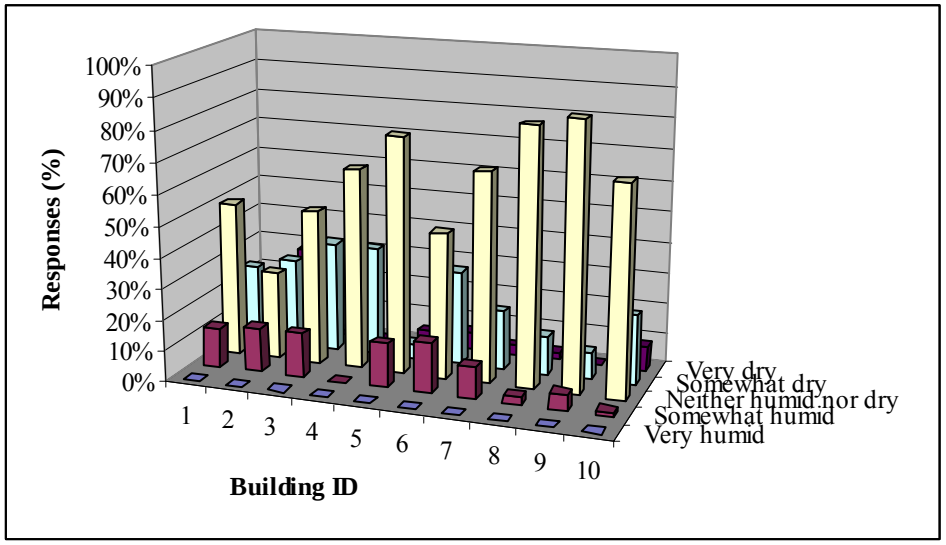


Figure M32. Summary of occupants' responses on the perception questionnaire when asked how humid the air in their work area is throughout the afternoons.

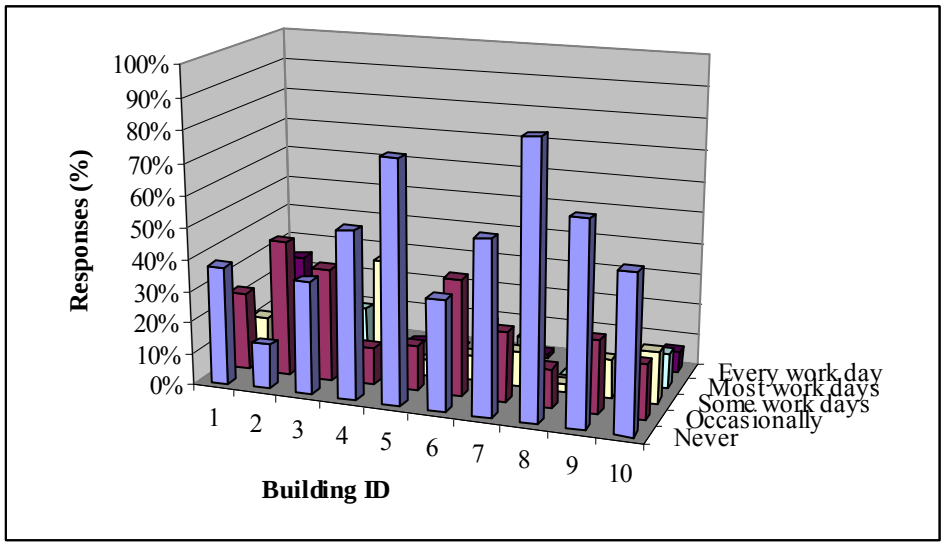


Figure M33. Summary of occupants' responses on the perception questionnaire when asked how often the air in their work area is too dry.

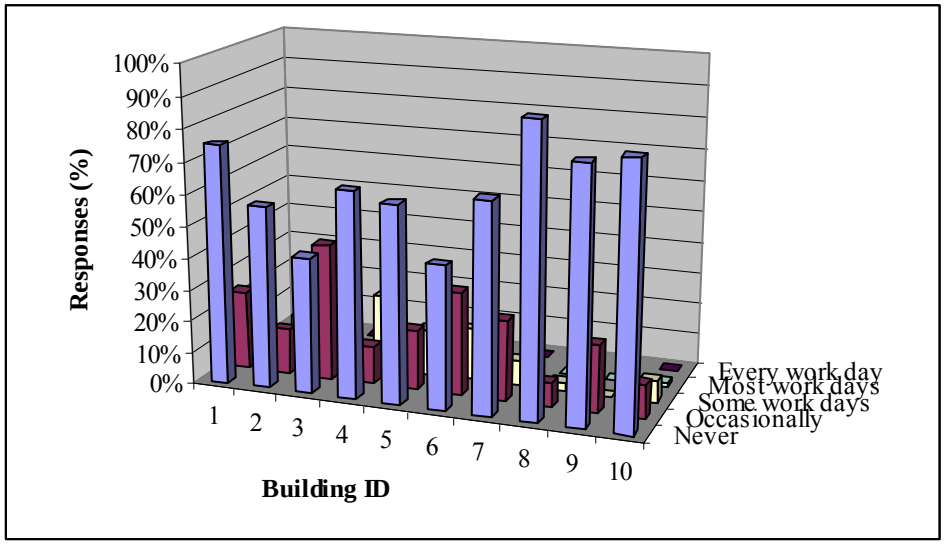


Figure M34. Summary of occupants' responses on the perception questionnaire when asked how often the air in their work area is too humid.

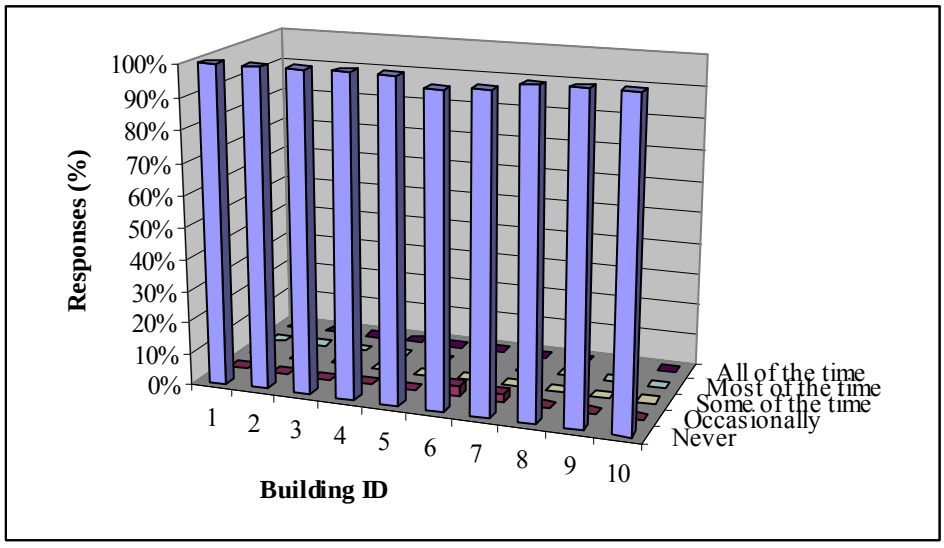


Figure M35. Summary of occupants' responses on the perception questionnaire when asked how often they use a personal humidifier when the air in their work area is too dry.

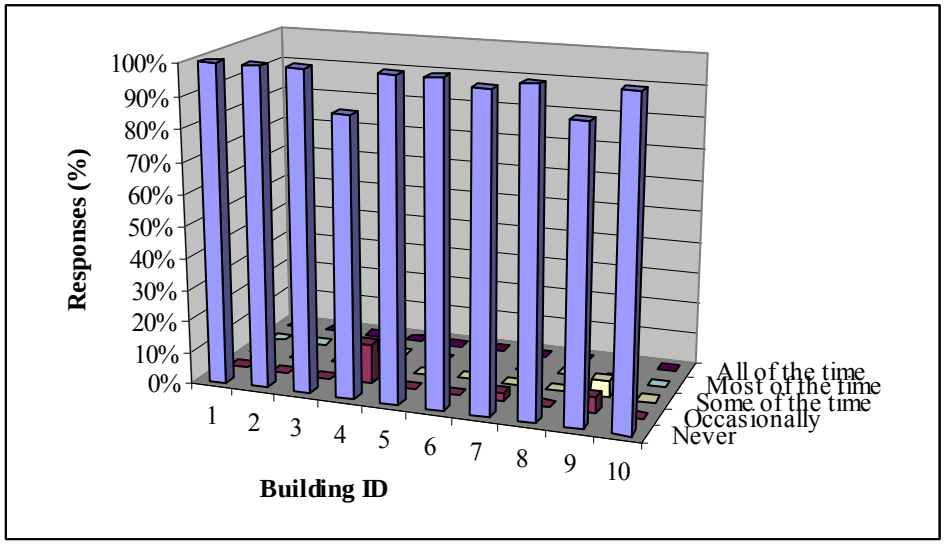


Figure M36. Summary of occupants' responses on the perception questionnaire when asked how often they adjust the thermostat when the air in their work area is too dry.

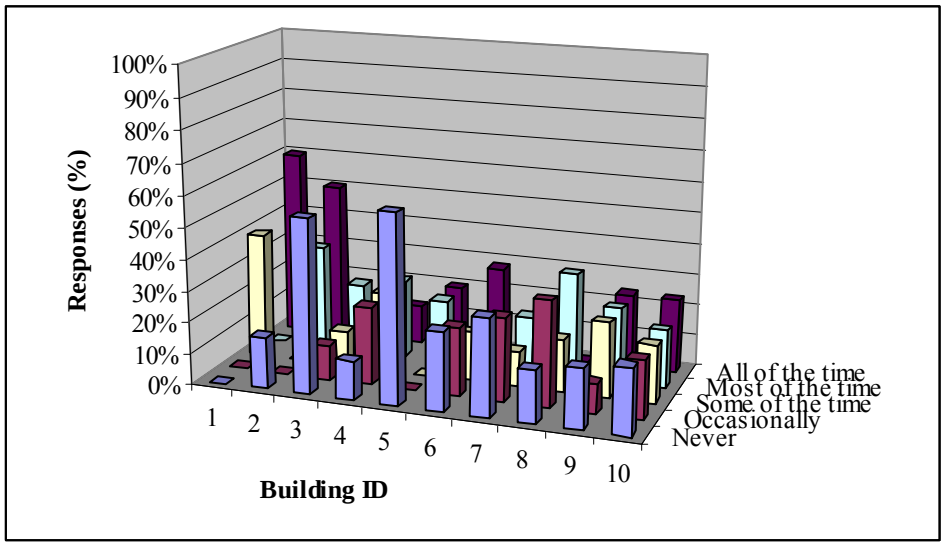


Figure M37. Summary of occupants' responses on the perception questionnaire when asked how often they use a moisturizer/lotion on their skin when the air in their work area is too dry.

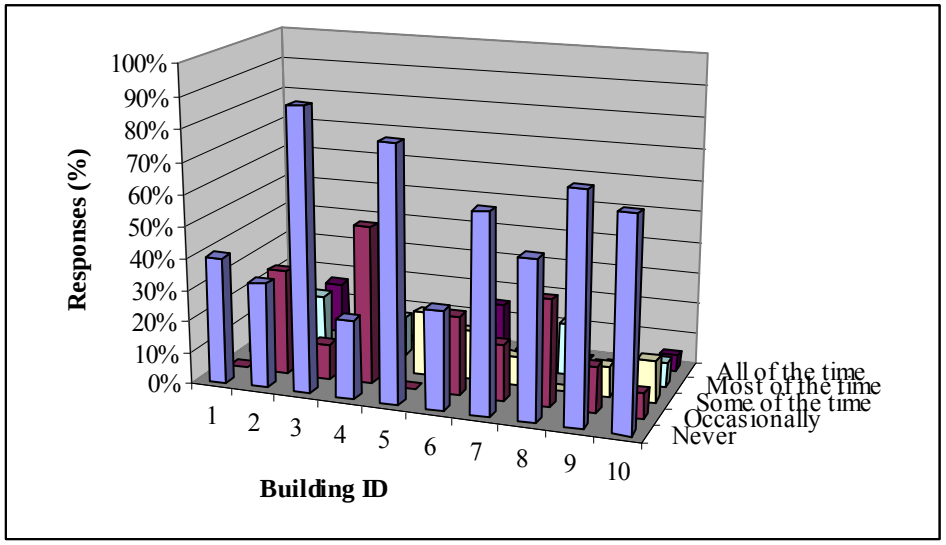


Figure M38. Summary of occupants' responses on the perception questionnaire when asked how often they use lubricant drops in their eyes when the air in their work area is too dry.

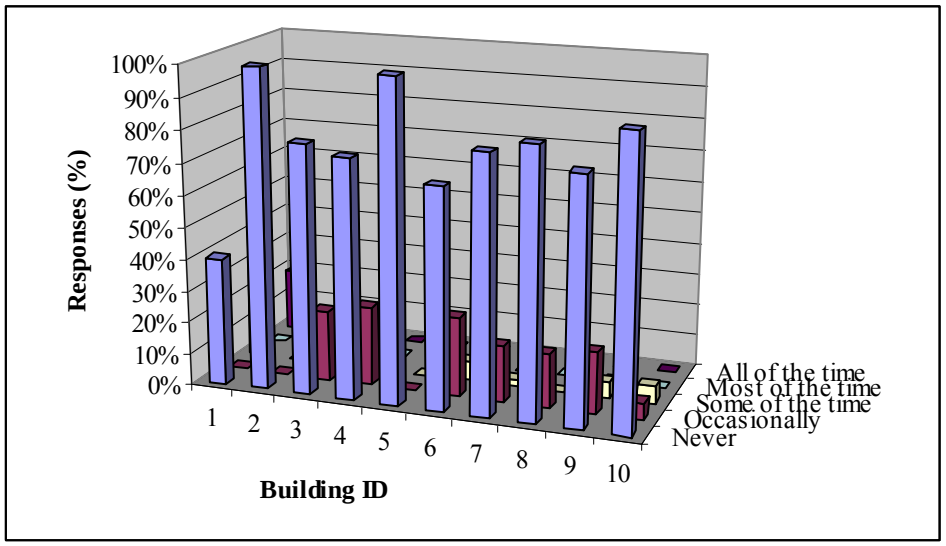


Figure M39. Summary of occupants' responses on the perception questionnaire when asked how often they report to management or facilities personnel when the air in their work area is too dry.

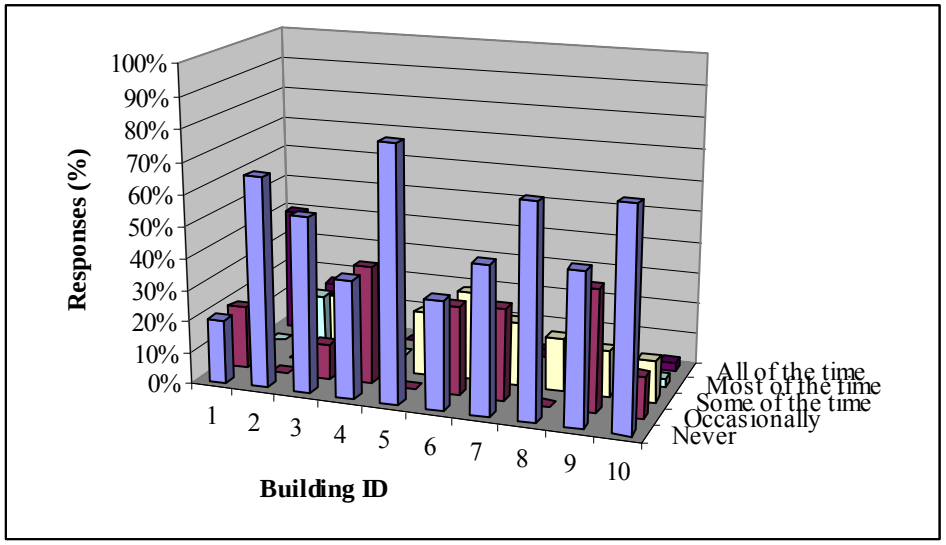


Figure M40. Summary of occupants' responses on the perception questionnaire when asked how often they mention to co-workers when the air in their work area is too dry.

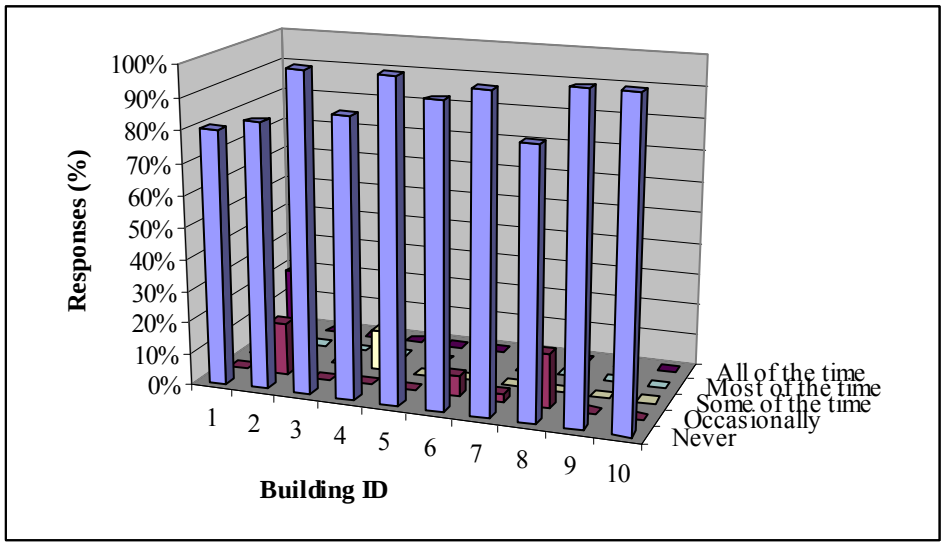


Figure M41. Summary of occupants' responses on the perception questionnaire when asked how often they open/close a door when the air in their work area is too dry.

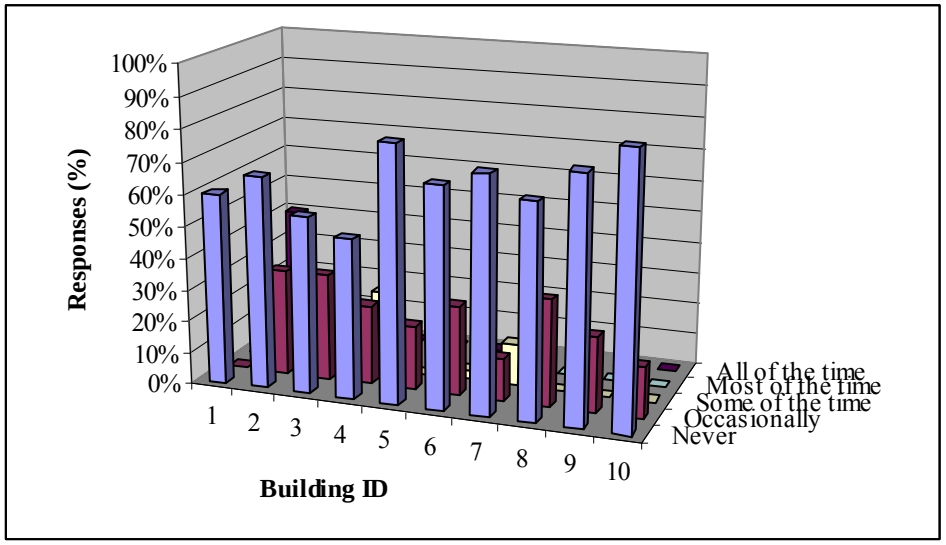


Figure M42. Summary of occupants' responses on the perception questionnaire when asked how often they temporarily leave their work area when the air in their work area is too dry.

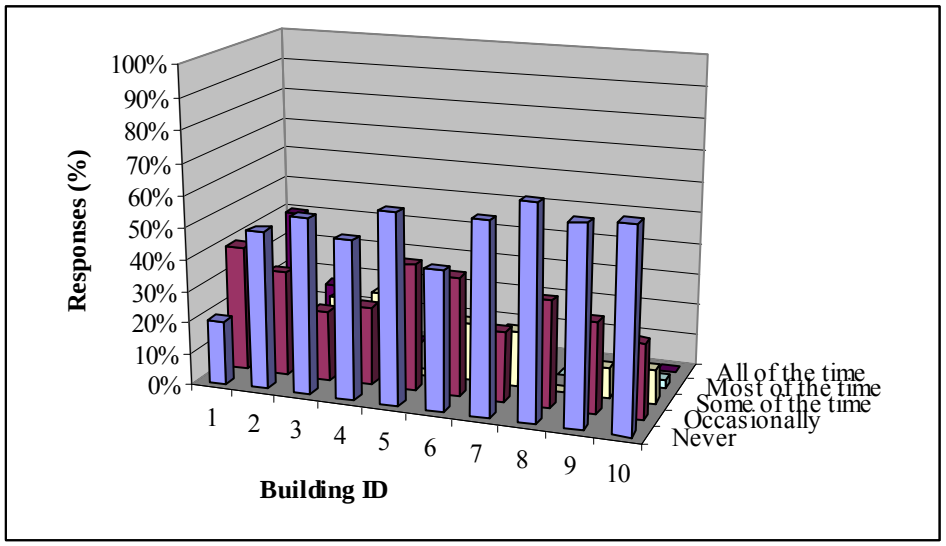


Figure M43. Summary of occupants' responses on the perception questionnaire when asked how often their productivity is adversely affected when the air in their work area is too dry.

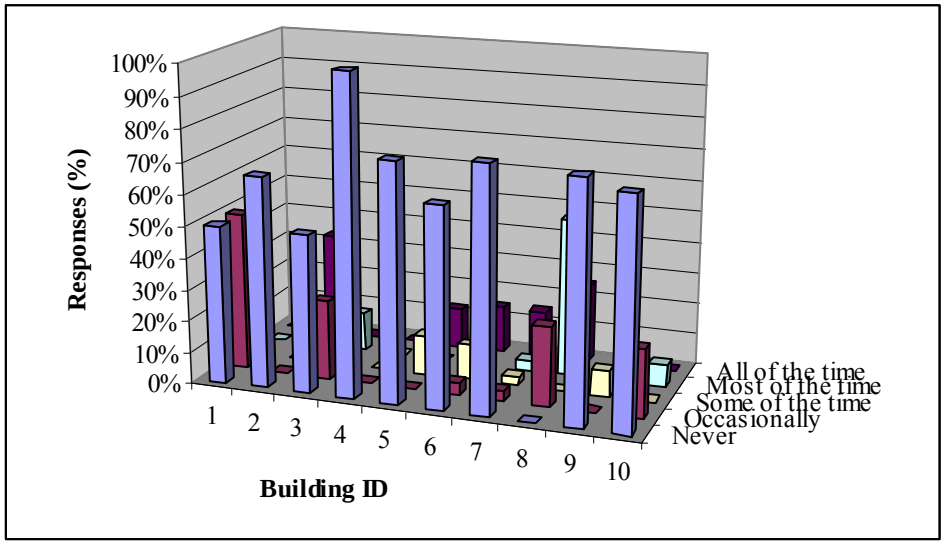


Figure M44. Summary of occupants' responses on the perception questionnaire when asked how often they use a personal fan when the air in their work area is too humid.

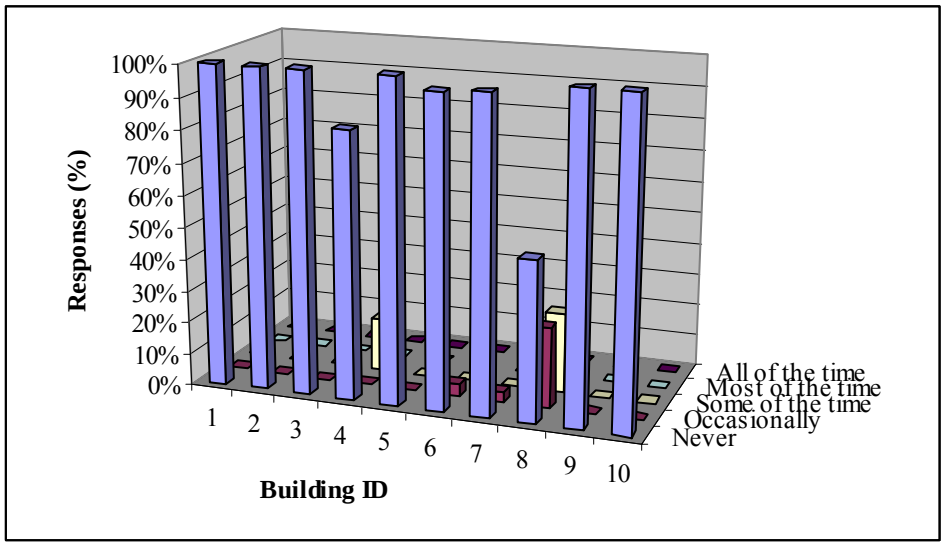


Figure M45. Summary of occupants' responses on the perception questionnaire when asked how often they adjust the thermostat when the air in their work area is too humid.

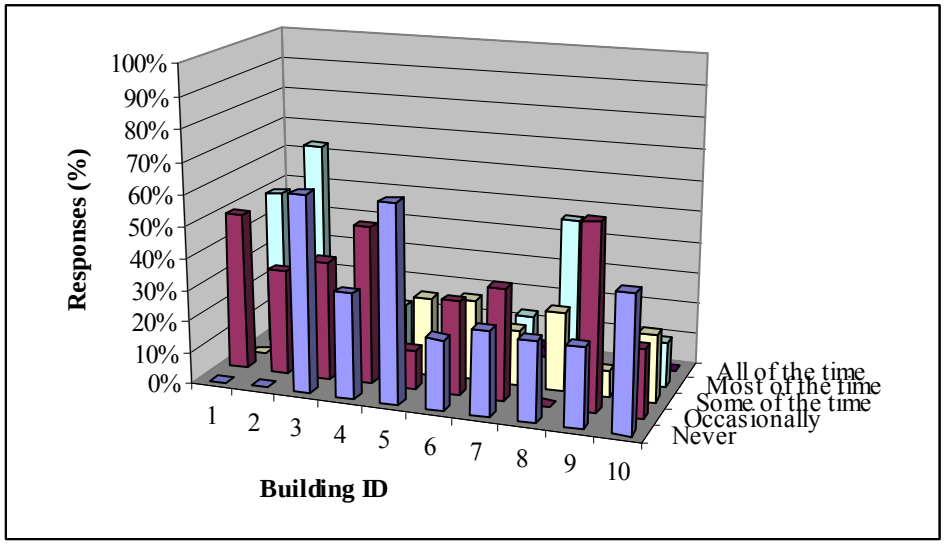


Figure M46. Summary of occupants' responses on the perception questionnaire when asked how often they put on lighter clothing or remove clothing when the air in their work area is too humid.

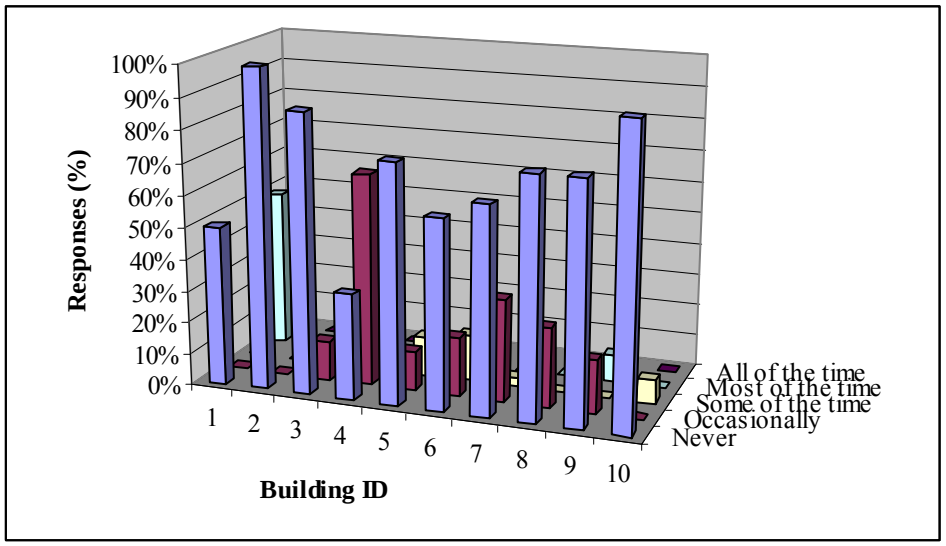


Figure M47. Summary of occupants' responses on the perception questionnaire when asked how often they report to management or facilities personnel when the air in their work area is too humid.

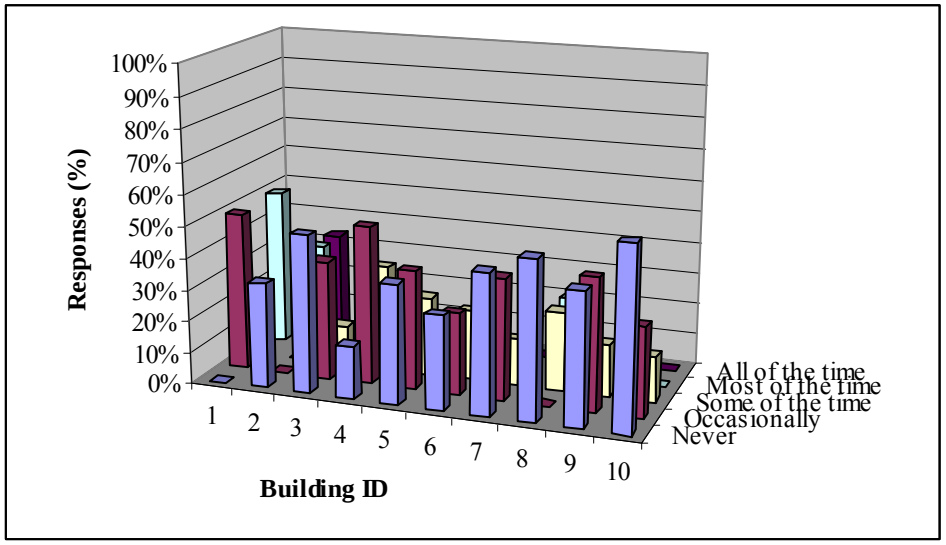


Figure M48. Summary of occupants' responses on the perception questionnaire when asked how often they mention to co-workers when the air in their work area is too humid.

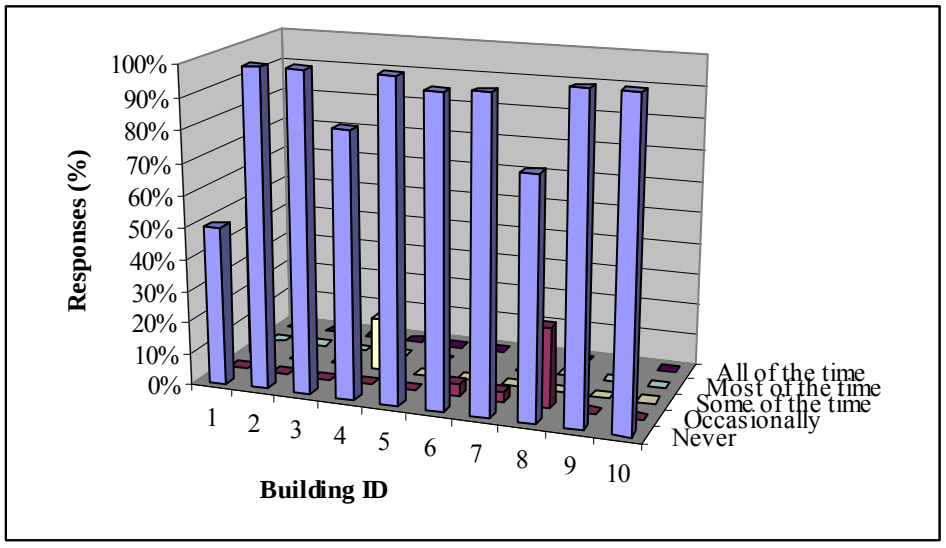


Figure M49. Summary of occupants' responses on the perception questionnaire when asked how often they open/close a door when the air in their work area is too humid.

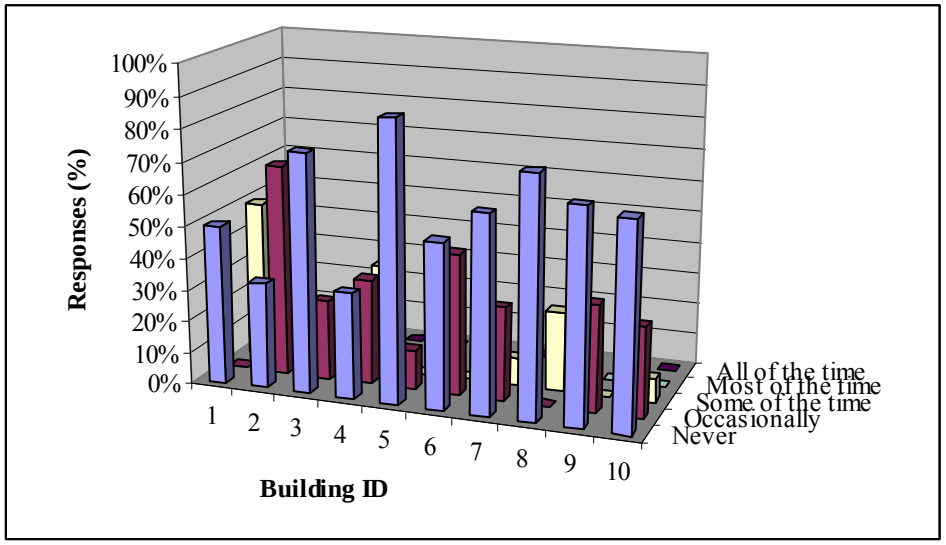


Figure M50. Summary of occupants' responses on the perception questionnaire when asked how often they temporarily leave their work area when the air in their work area is too humid.

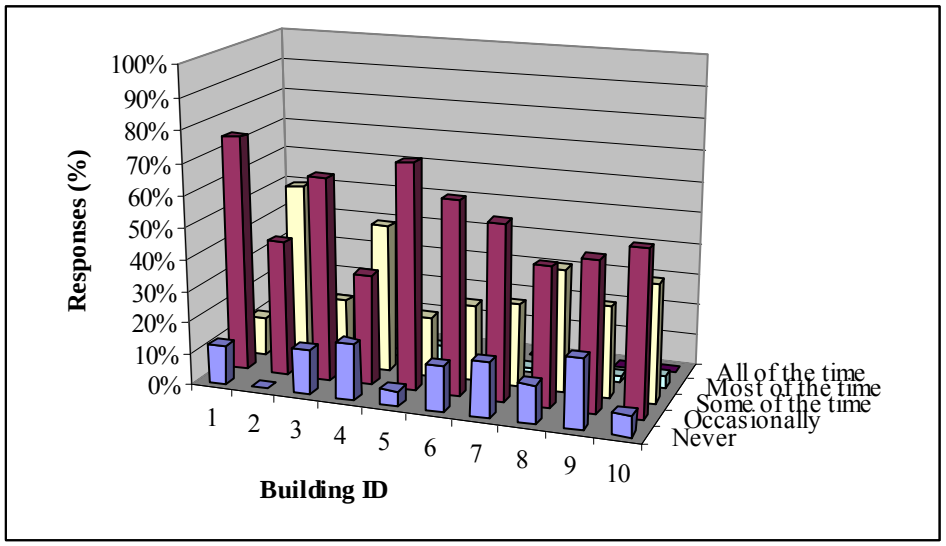


Figure M51. Summary of occupants' responses on the perception questionnaire when asked how often their productivity is adversely affected when the air in their work area is too humid.

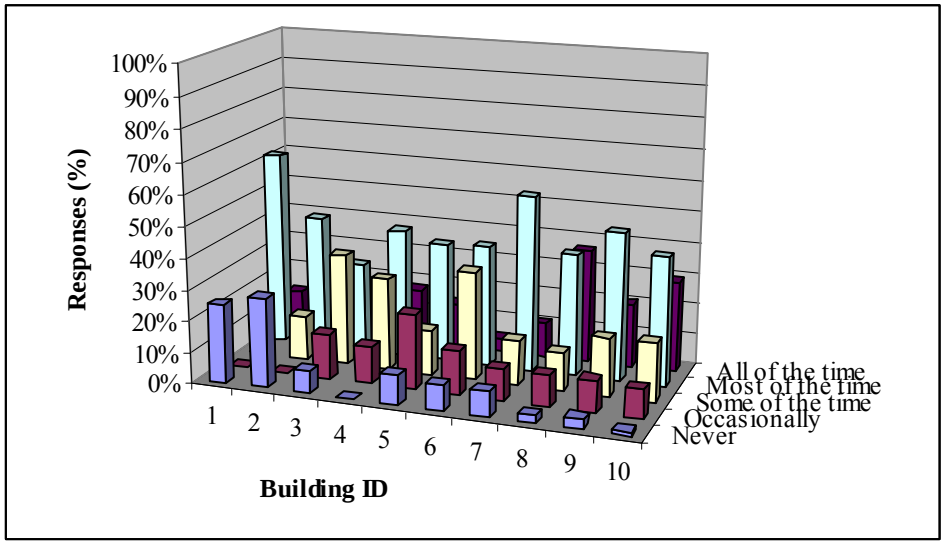


Figure M52. Summary of occupants' responses on the perception questionnaire when asked how often the movement of air in their work area is acceptable.

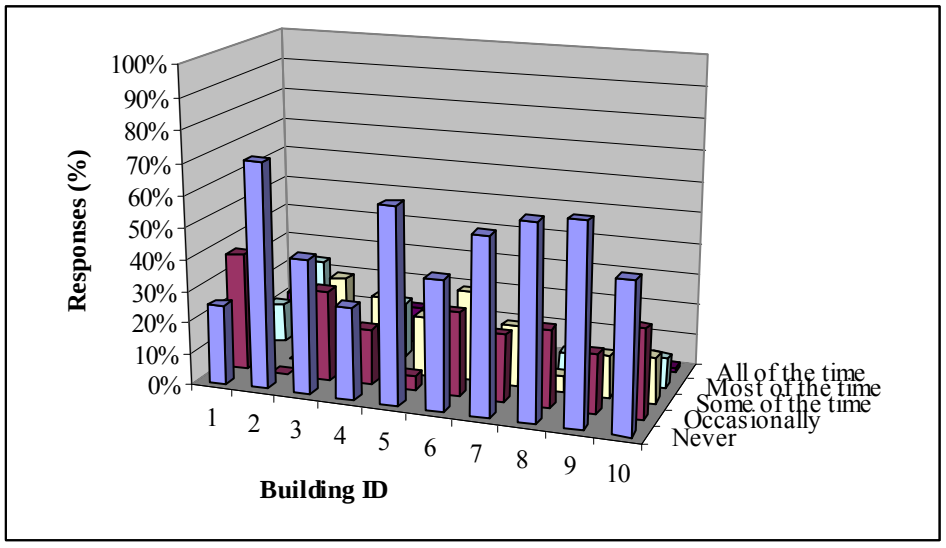


Figure M53. Summary of occupants' responses on the perception questionnaire when asked how often the air in their work area fluctuates from drafty to stagnant and vice versa throughout the course of an entire work day.

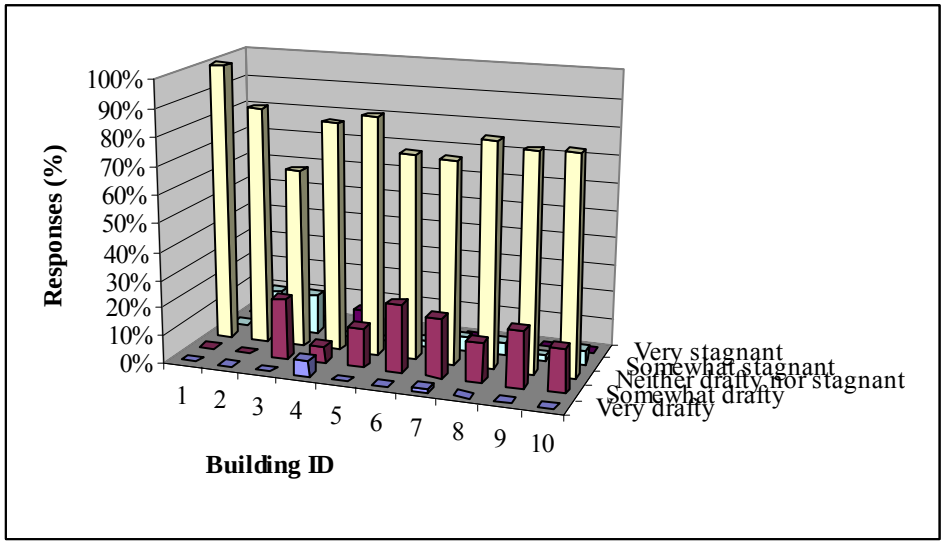


Figure M54. Summary of occupants' responses on the perception questionnaire when asked the movement of air in their work area when they are the most comfortable.

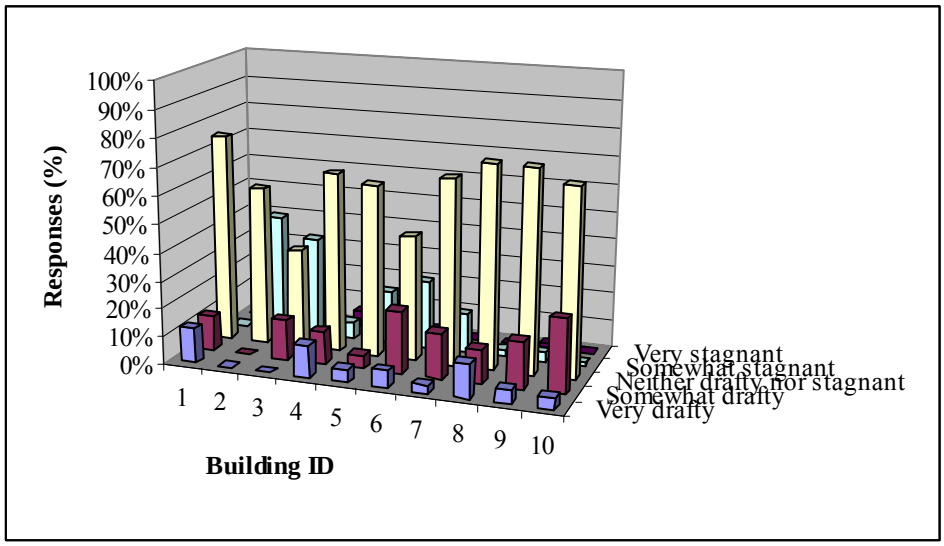


Figure M55. Summary of occupants' responses on the perception questionnaire when asked the movement of air in their work area throughout the mornings.

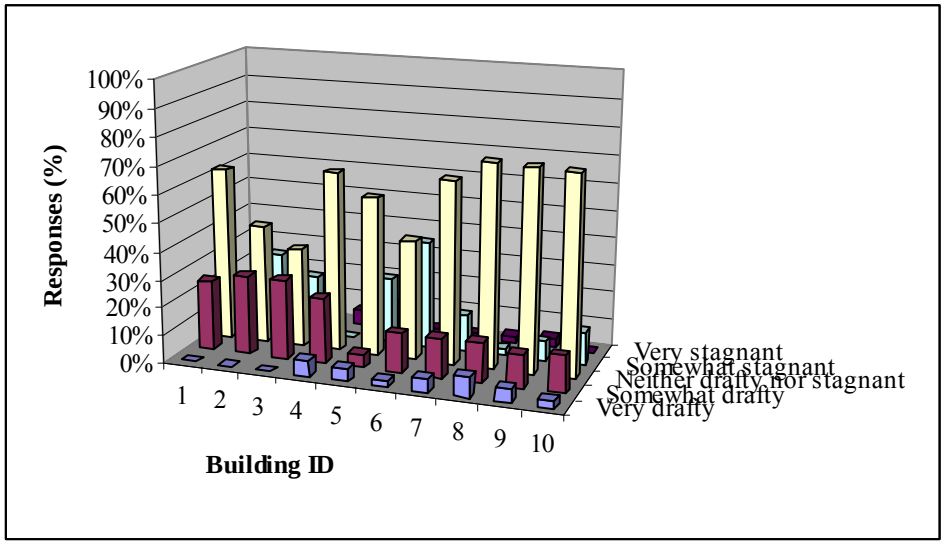


Figure M56. Summary of occupants' responses on the perception questionnaire when asked the movement of air in their work area throughout the afternoons.

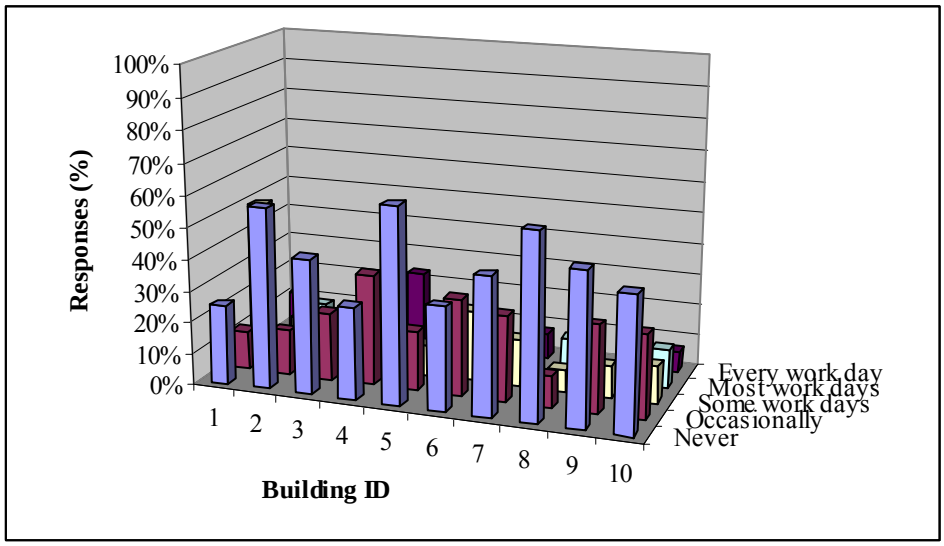


Figure M57. Summary of occupants' responses on the perception questionnaire when asked how often they feel a draft in the air in their work area.

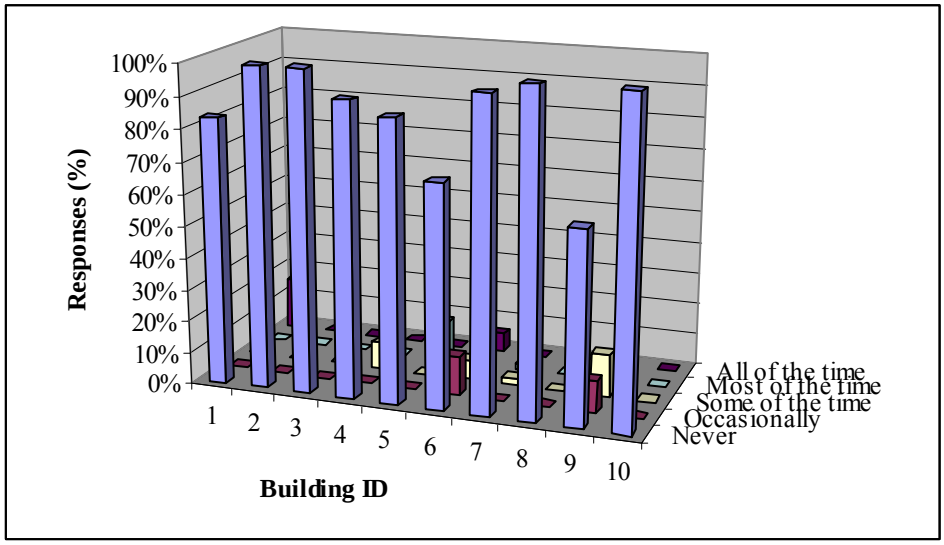


Figure M58. Summary of occupants' responses on the perception questionnaire when asked how often they block or unblock air supply registers when they feel a draft in their work area.

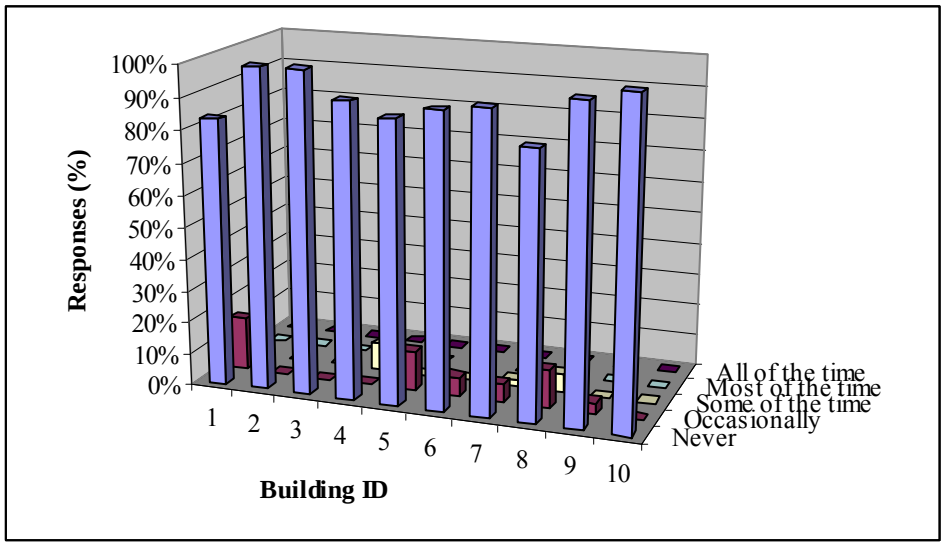


Figure M59. Summary of occupants' responses on the perception questionnaire when asked how often they open/close a door when they feel a draft in their work area.

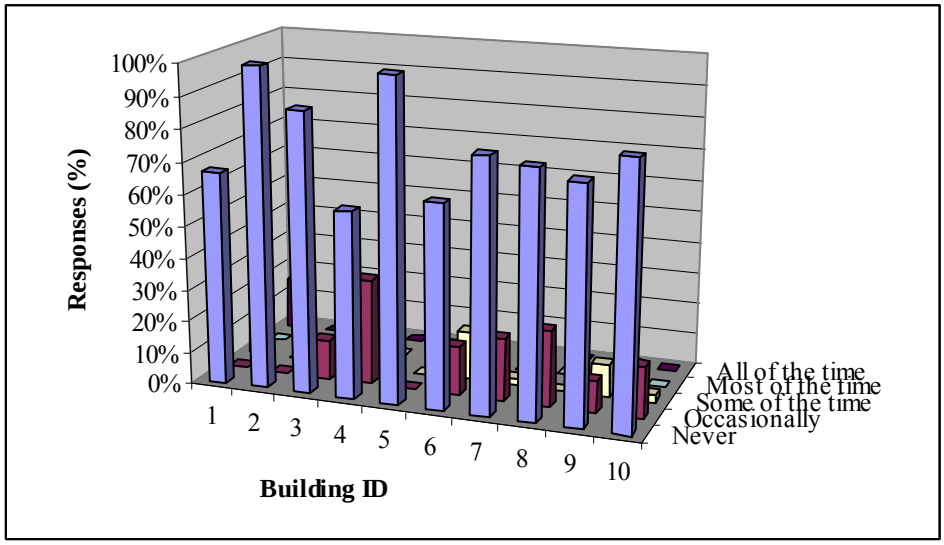


Figure M60. Summary of occupants' responses on the perception questionnaire when asked how often they report to management or facilities personnel when they feel a draft in their work area.

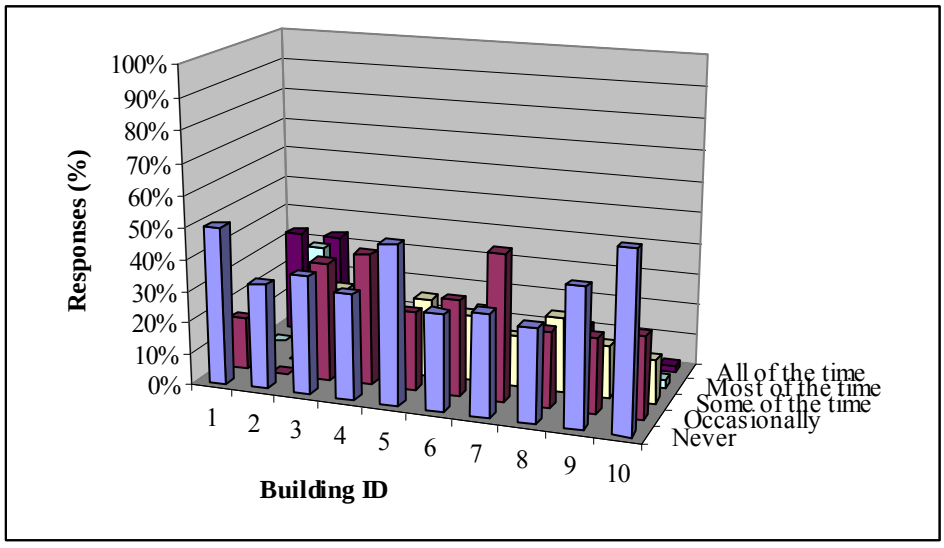


Figure M61. Summary of occupants' responses on the perception questionnaire when asked how often they mention to co-workers when they feel a draft in their work area.

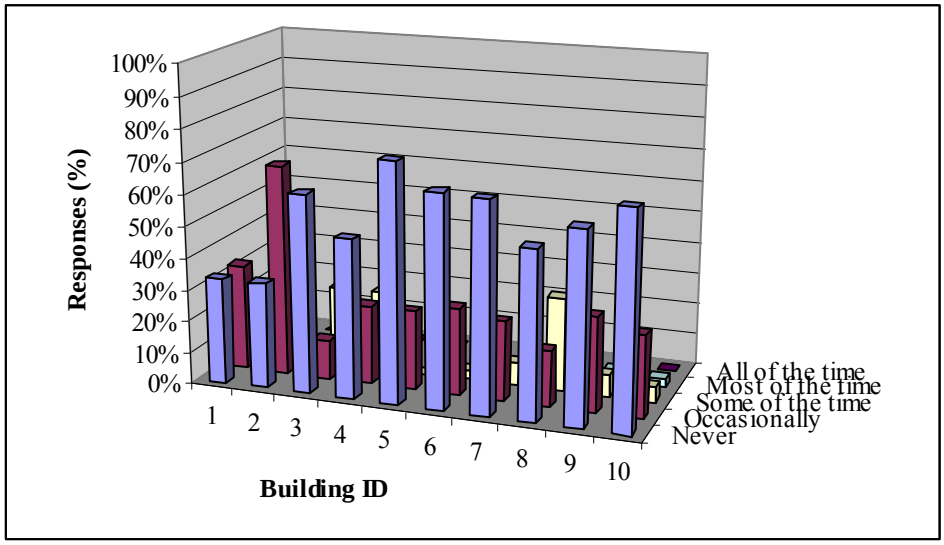


Figure M62. Summary of occupants' responses on the perception questionnaire when asked how often they temporarily leave their work area when they feel a draft in their work area.

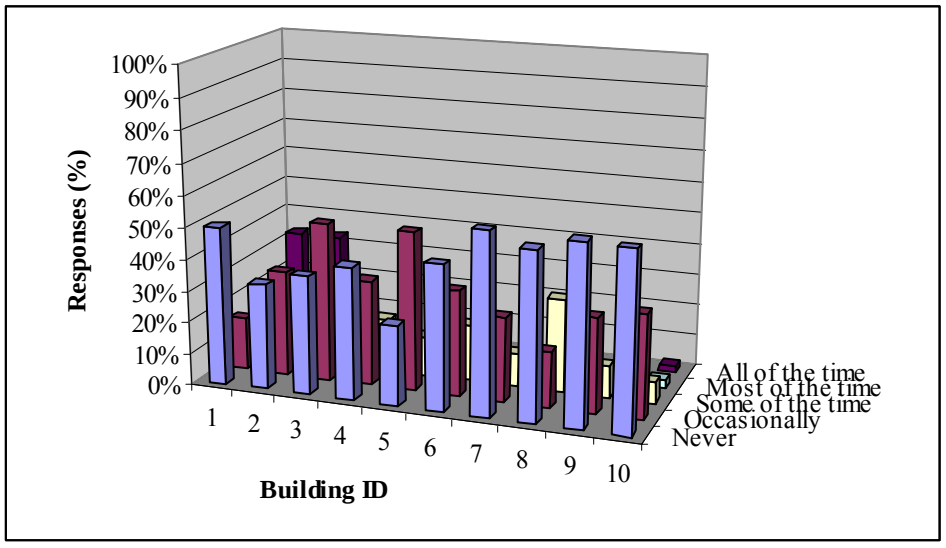


Figure M63. Summary of occupants' responses on the perception questionnaire when asked how often their productivity is adversely affected when they feel a draft in their work area.

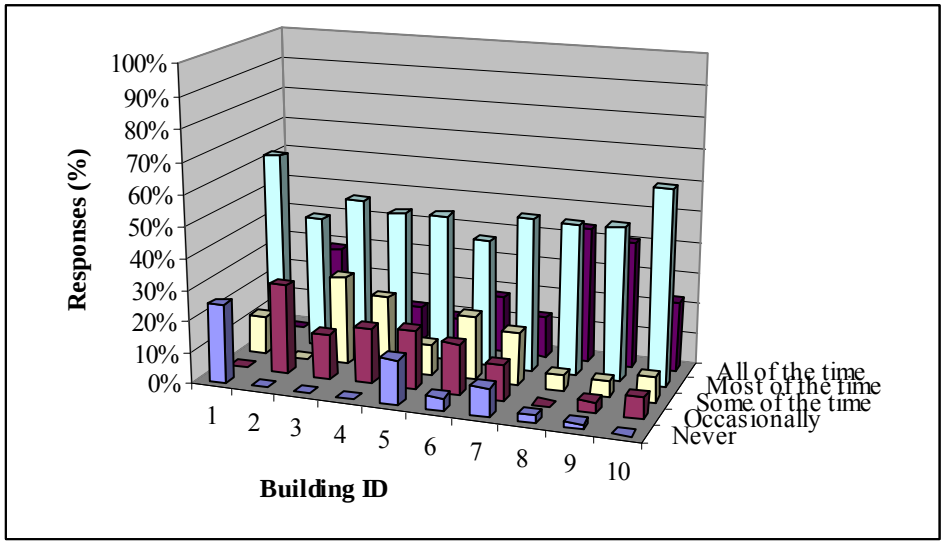


Figure M64. Summary of occupants' responses on the perception questionnaire when asked how often the freshness of air in their work area is acceptable.

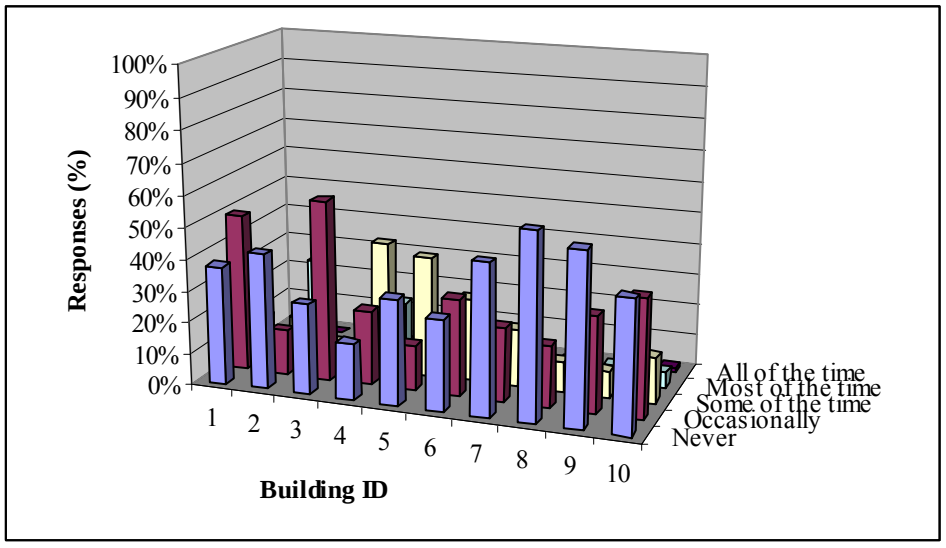


Figure M65. Summary of occupants' responses on the perception questionnaire when asked how often the air fluctuates between fresh and stuffy throughout the course of an entire work day.

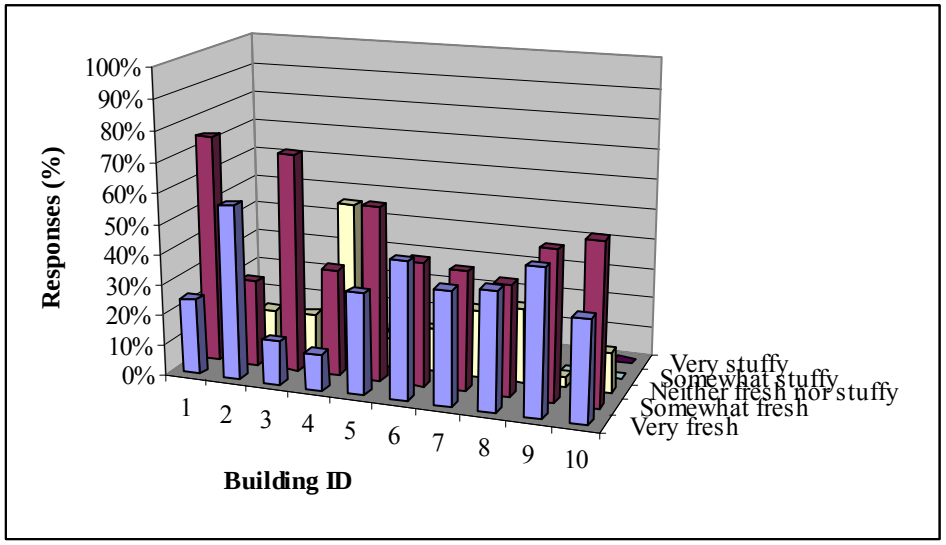


Figure M66. Summary of occupants' responses on the perception questionnaire when asked the freshness of air in their work area when they are the most comfortable.

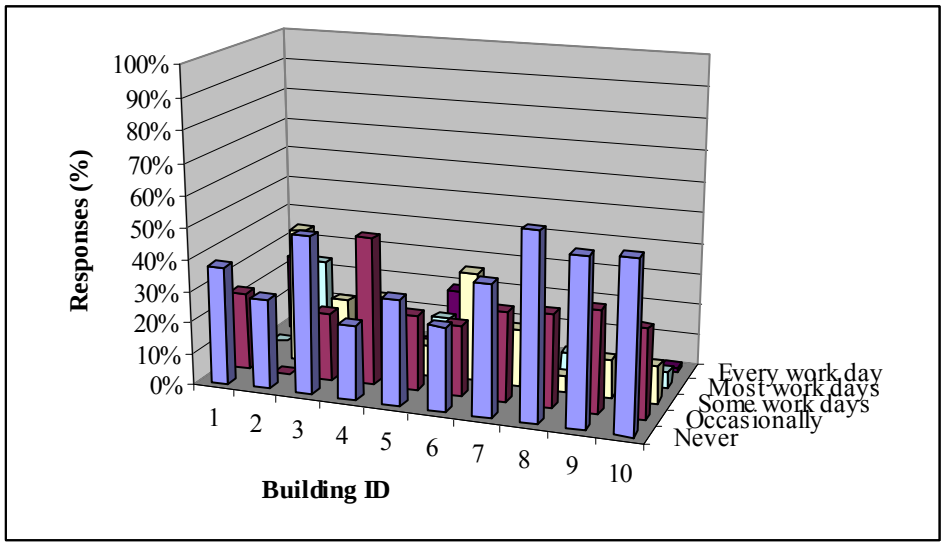


Figure M67. Summary of occupants' responses on the perception questionnaire when asked how often the air in their work area is too stuffy.

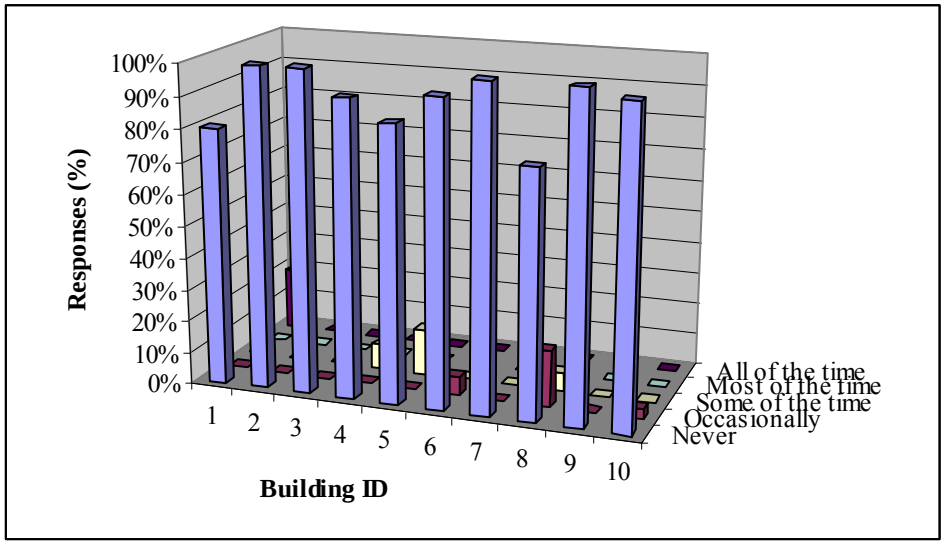


Figure M68. Summary of occupants' responses on the perception questionnaire when asked how often they adjust the thermostat when the air in their work area is too stuffy.

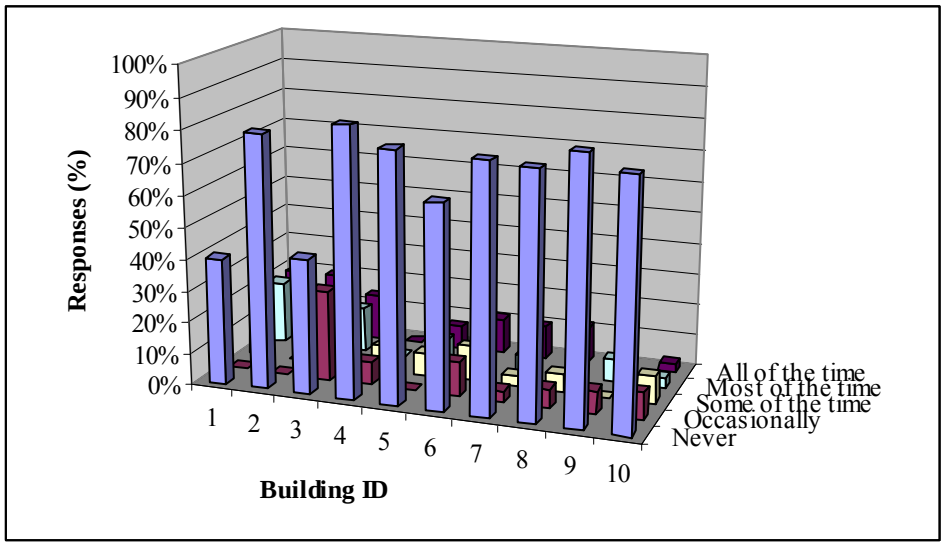


Figure M69. Summary of occupants' responses on the perception questionnaire when asked how often they use a personal fan when the air in their work area is too stuffy.

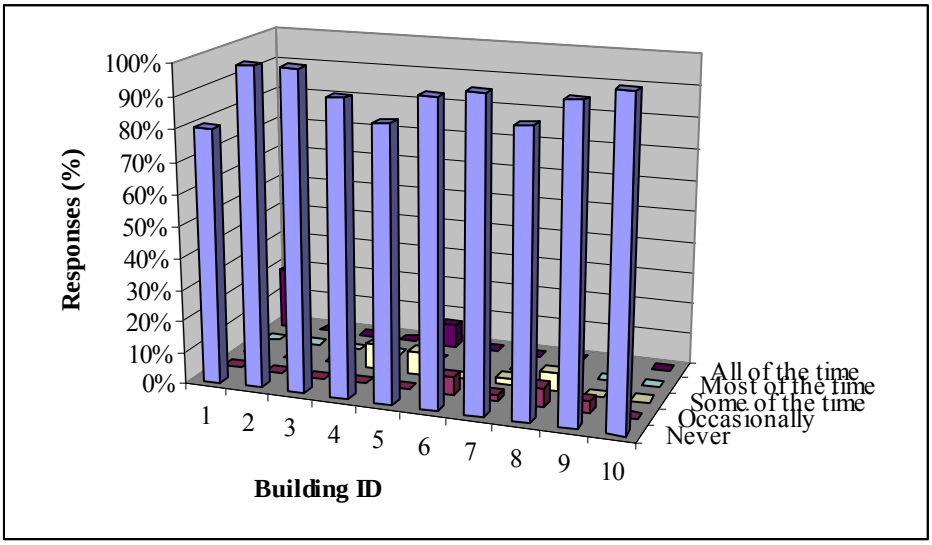


Figure M70. Summary of occupants' responses on the perception questionnaire when asked how often they open/close a door when the air in their work area is too stuffy.

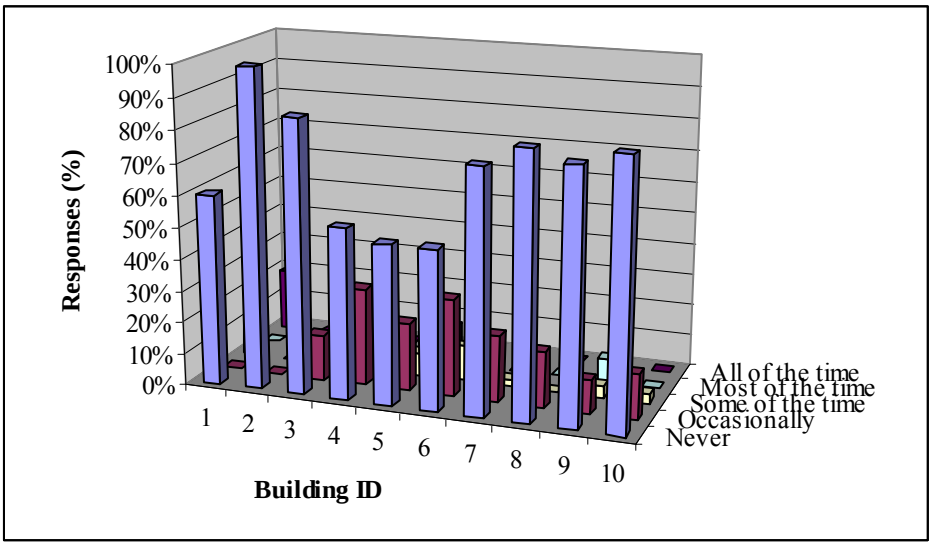


Figure M71. Summary of occupants' responses on the perception questionnaire when asked how often they report to management or facilities personnel when the air in their work area is too stuffy.

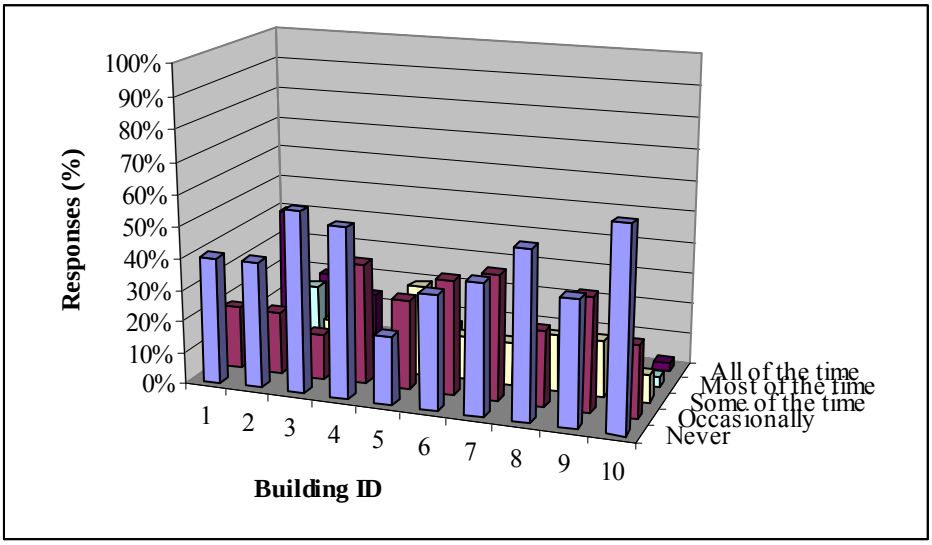


Figure M72. Summary of occupants' responses on the perception questionnaire when asked how often they mention to co-workers when the air in their work area is too stuffy.

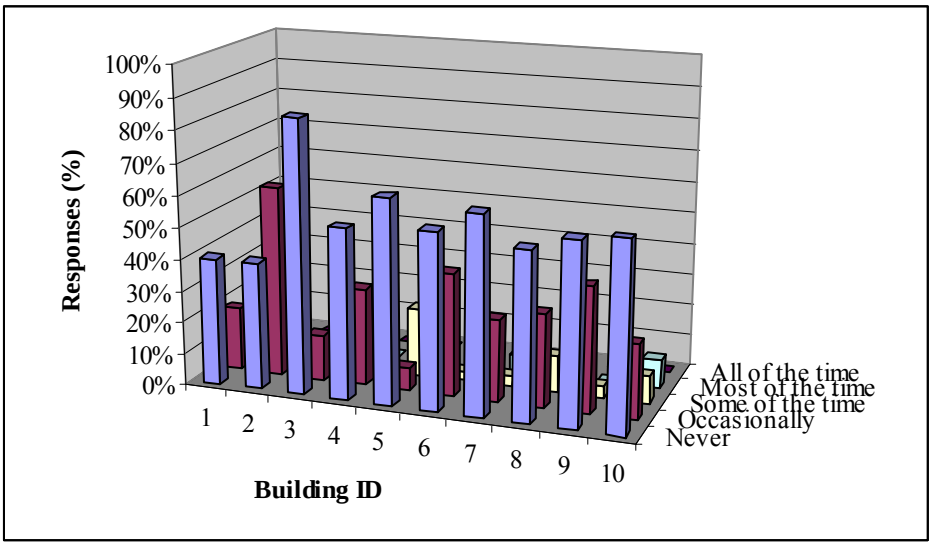


Figure M73. Summary of occupants' responses on the perception questionnaire when asked how often they temporarily leave their work area when the air in their work area is too stuffy.

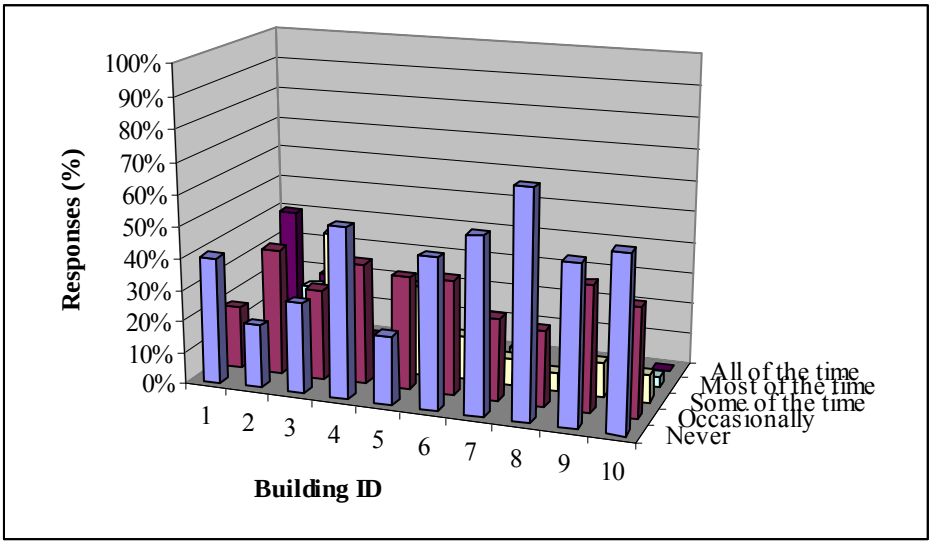


Figure M74. Summary of occupants' responses on the perception questionnaire when asked how often their productivity is adversely affected when the air in their work area is too stuffy.

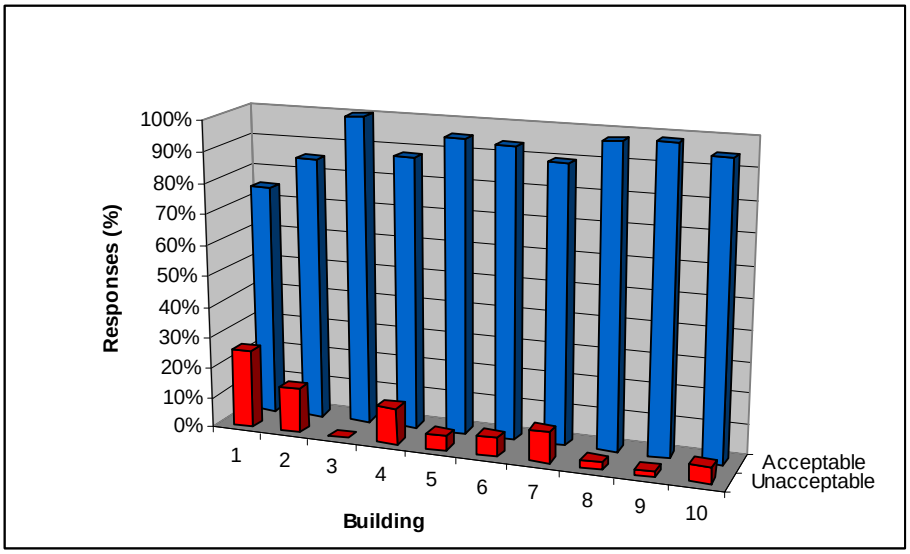


Figure M75. Summary of occupants' responses on the perception questionnaire when asked if the odors in their workplace were acceptable.

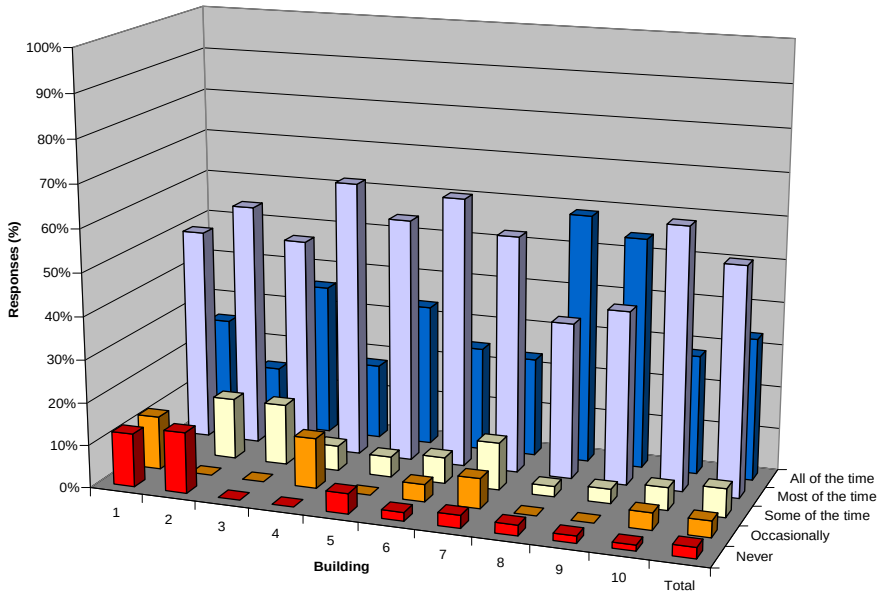


Figure M76. Summary of occupants' responses on the perception questionnaire when asked the frequency of acceptable odors in their workplace.

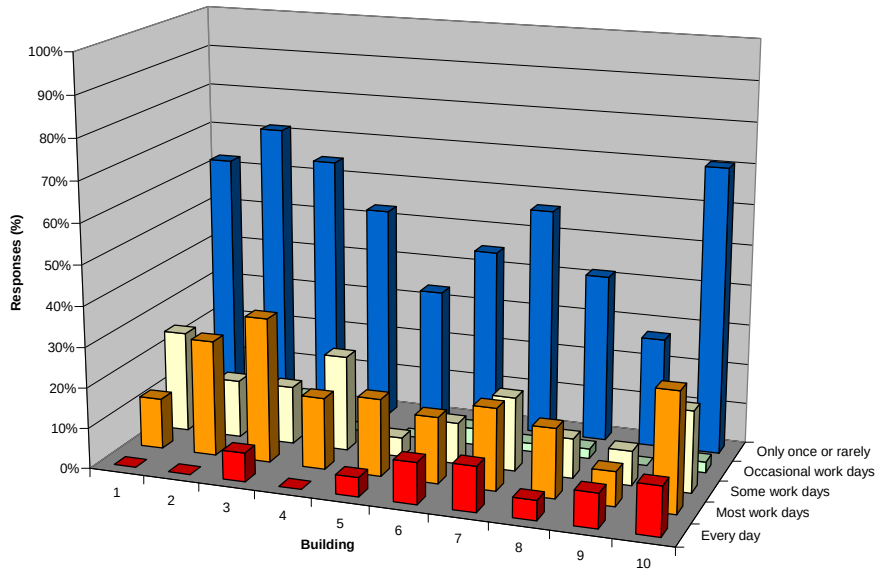


Figure M77. Summary of occupant responses on the perception questionnaire when asked the frequency of unacceptable odors in their workplace.

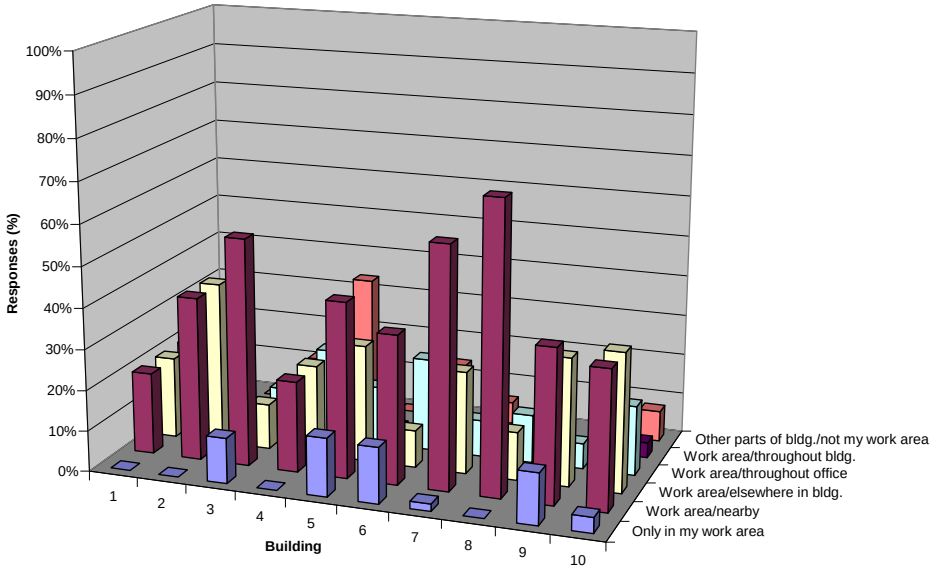


Figure M78. Summary of occupants' responses on the perception questionnaire when asked where they believed there were odors in their building.

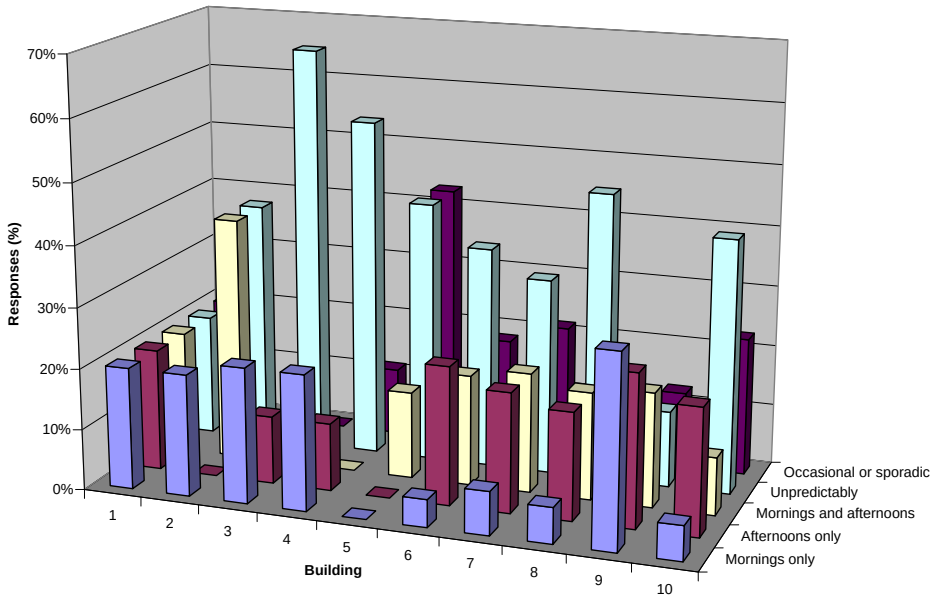


Figure M79. Summary of occupant responses on the perception questionnaire when asked when during the day there were unacceptable odors in their workplace.

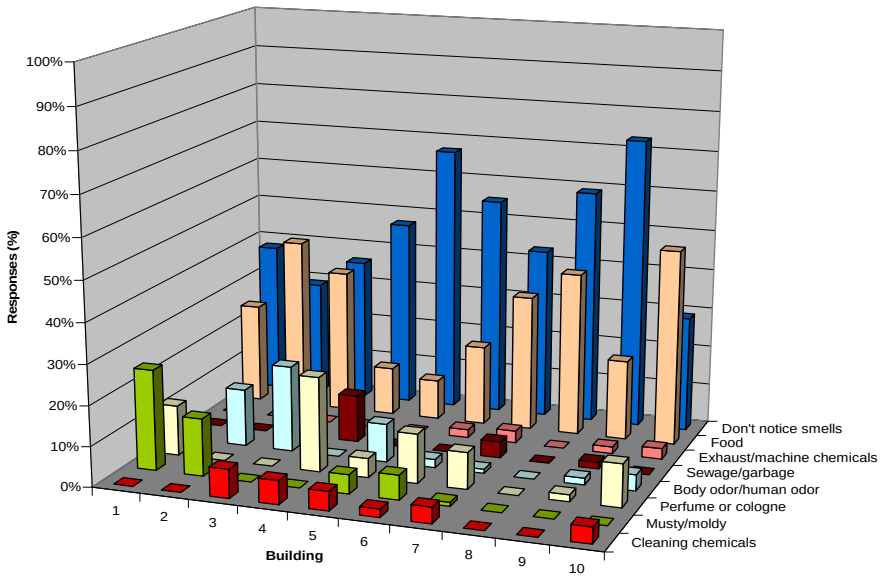


Figure M80. Summary of occupants' responses on the perception questionnaire when asked what they believed the sources of odors to be in their workplace.

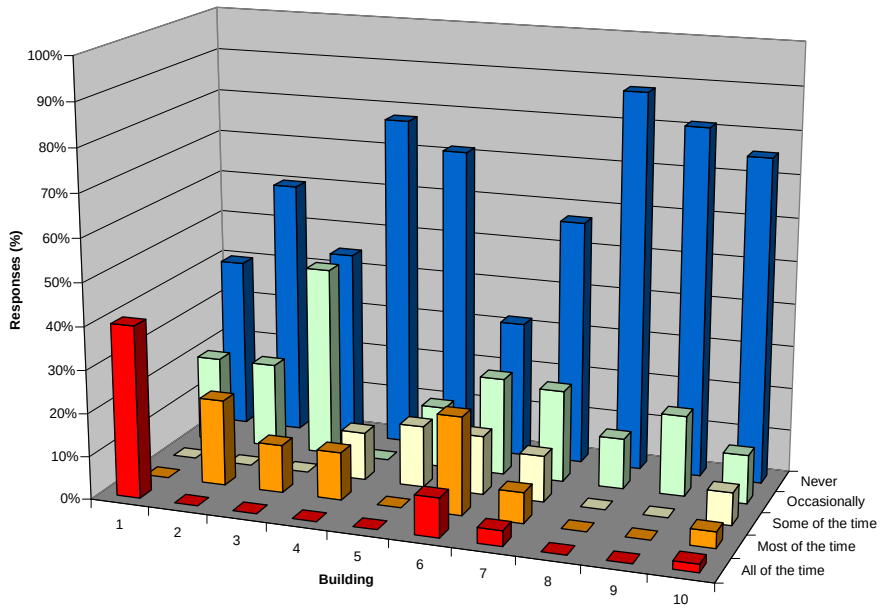


Figure M81. Summary of occupants' responses on the perception questionnaire when asked if when there was a noticeable odor it made them sneeze.

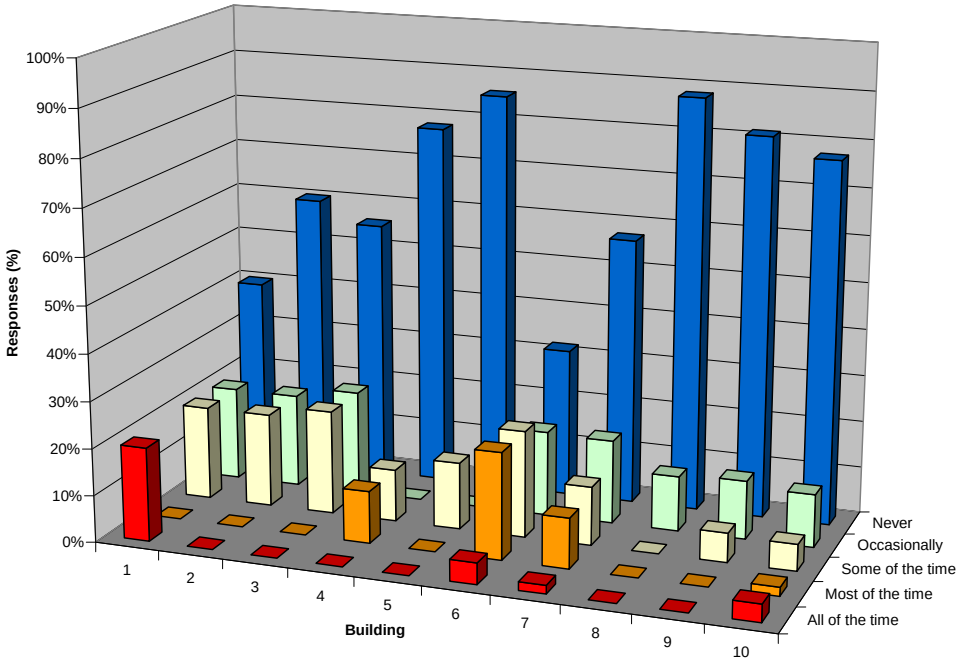


Figure M82. Summary of occupants' responses on the perception questionnaire when asked if when there was a noticeable odor it made them blow their nose.

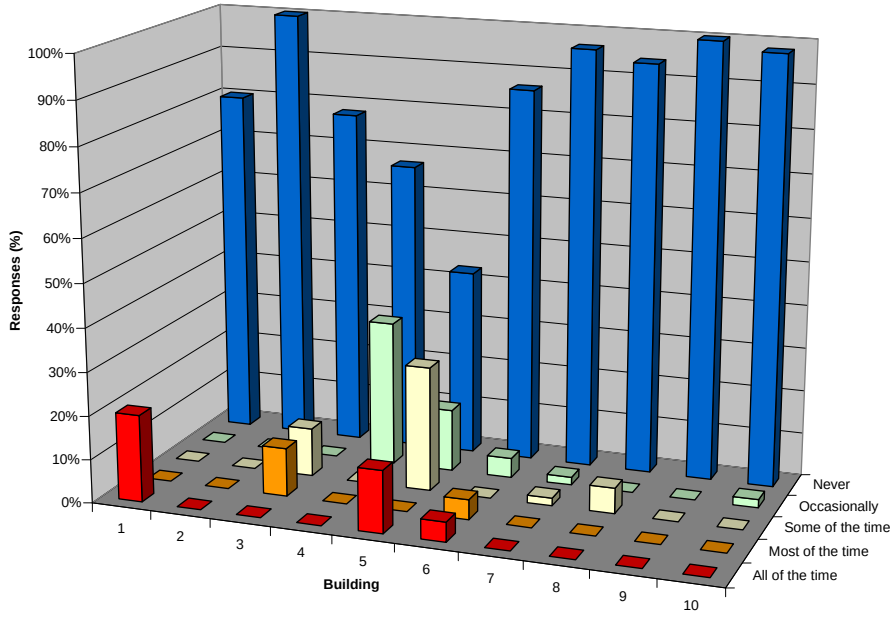


Figure M83. Summary of occupants' responses on the perception questionnaire when asked if when there was a noticeable odor they used an air freshner.

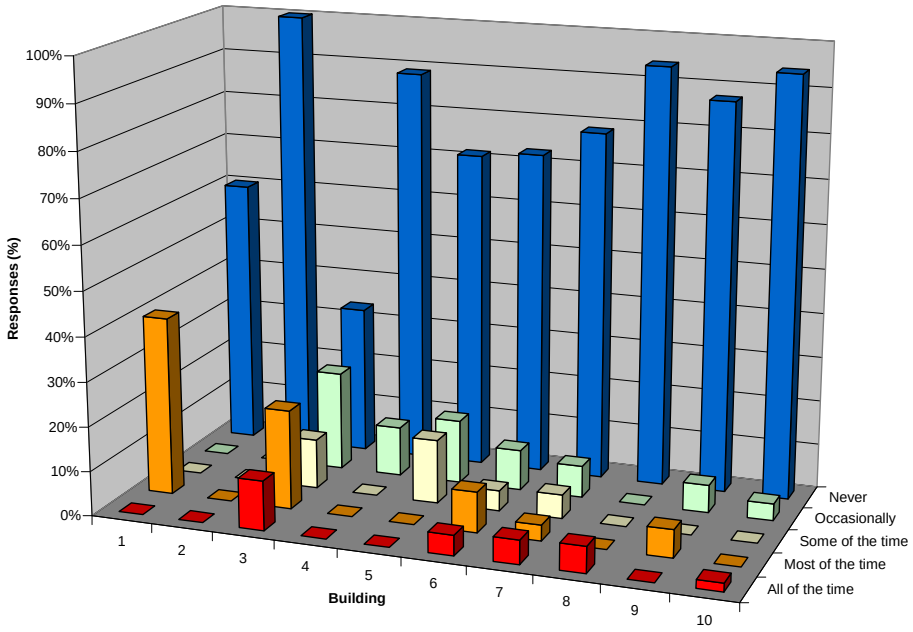


Figure M84. Summary of occupants' responses on the perception questionnaire when asked if when there was a noticeable odor they used a fan in their work area.

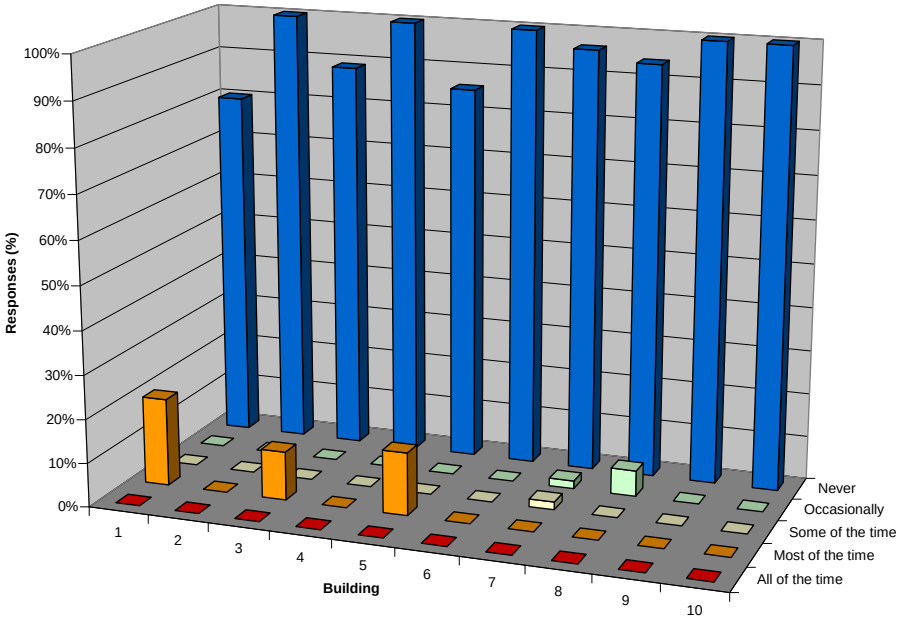


Figure M85. Summary of occupants' responses on the perception questionnaire when asked if when there was a noticeable odor in their building they closed a door.

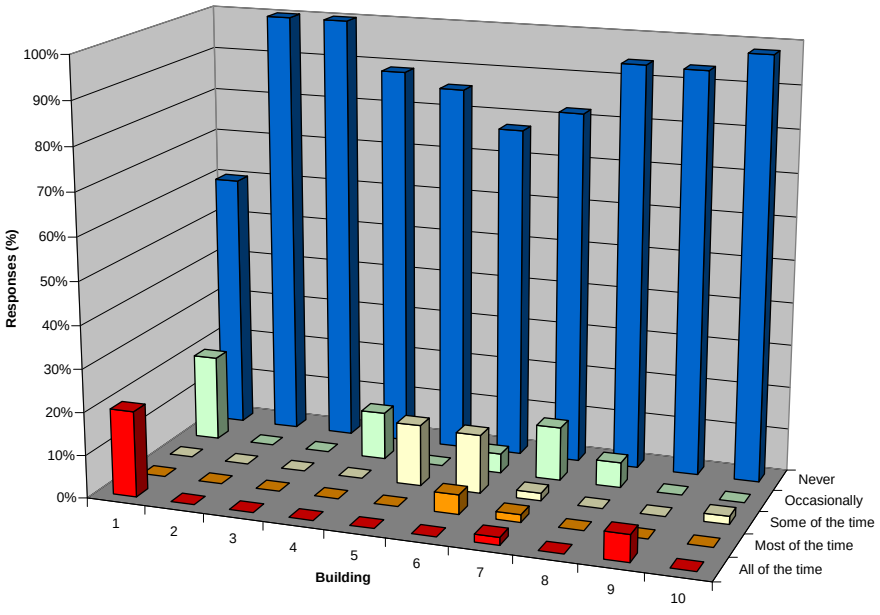


Figure M86. Summary of occupants' responses on the perception questionnaire when asked if they reported to management when there was a noticeable odor in their building.

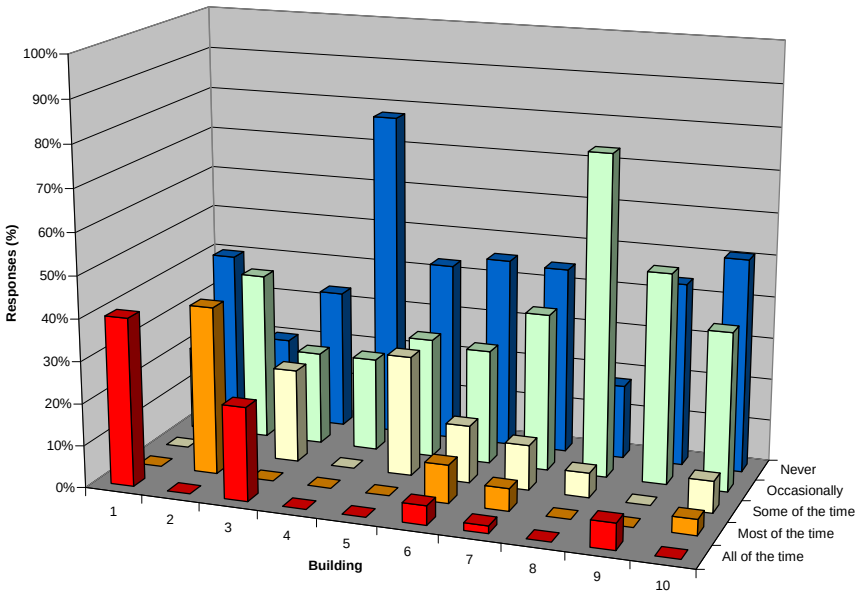


Figure M87. Summary of occupants' responses on the perception questionnaire when asked if they mentioned odors to others when there was a noticeable odor in their building.

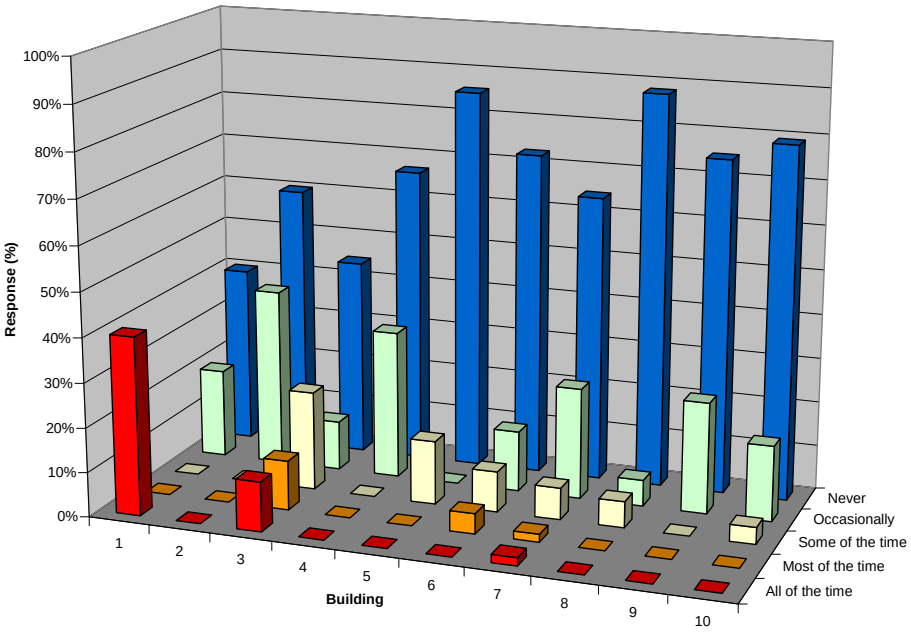


Figure M88. Summary of occupants' responses on the perception questionnaire when asked if they left the area when there was a noticeable odor in their building.

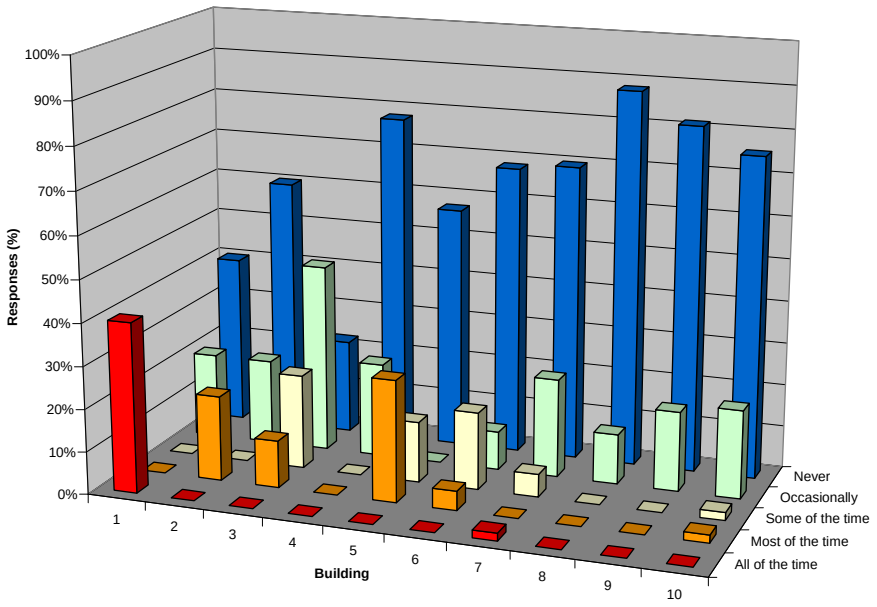


Figure M89. Summary of occupants' responses on the perception questionnaire when asked if when there was a noticeable odor in their building it affected their work.

APPENDIX N: AIRBORNE AND SURFACE-ASSOCIATED MOLD RESULTS

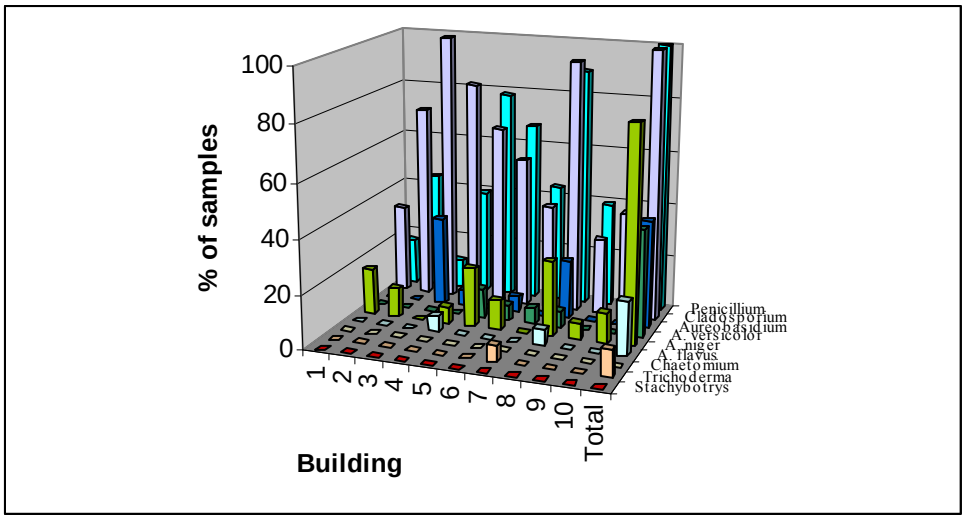


Figure N1. Percentage of samples in which selected fungal genera were isolated using the Andersen sampler reported as the percent (%) of samples by building and the percent of samples for all 10 buildings (total).

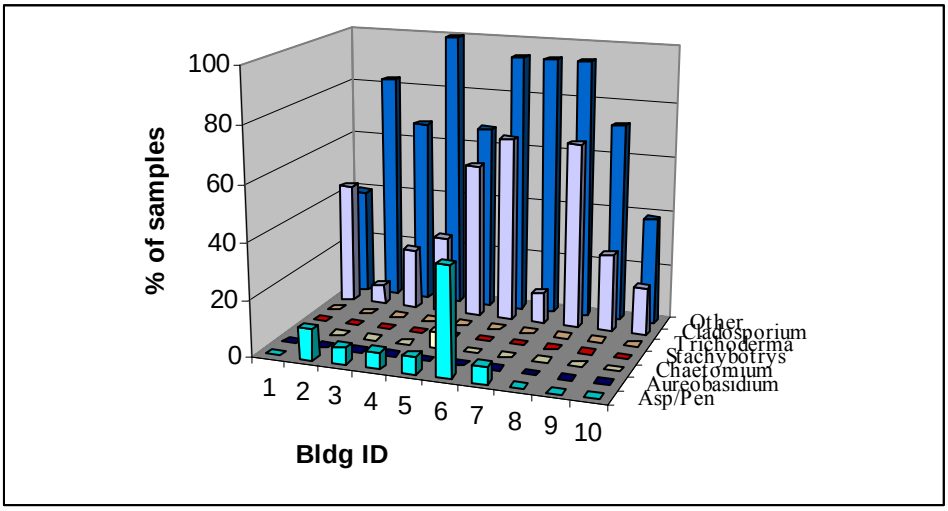


Figure N2. Percentage of samples in which selected fungal genera were observed using the Burkard sampler reported as the percent (%) of samples by building and the percent of samples for all 10 buildings (total).

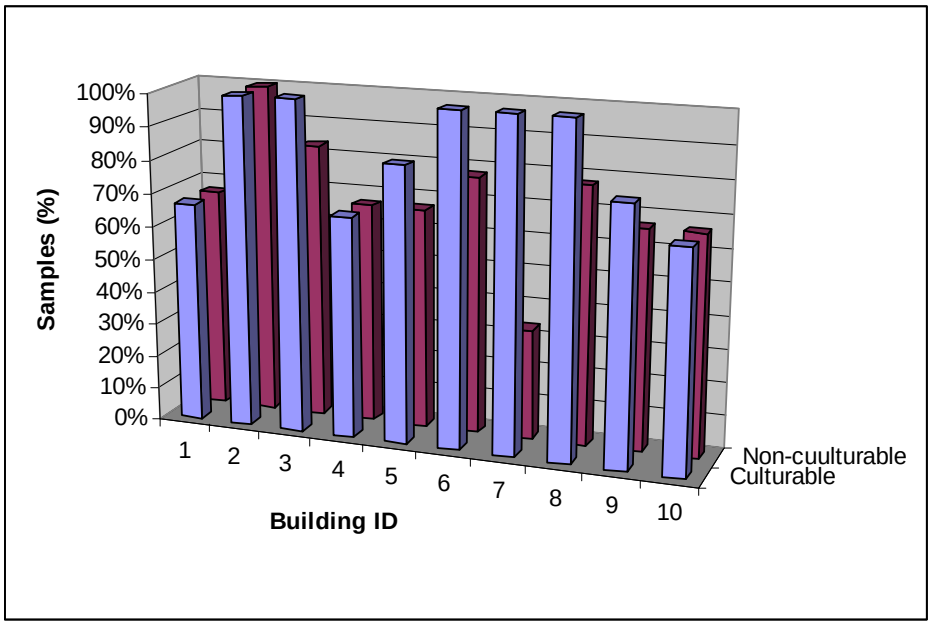


Figure N3. The percentage of outdoor culturable and non-culturable air samples in which a predominant organism was observed.

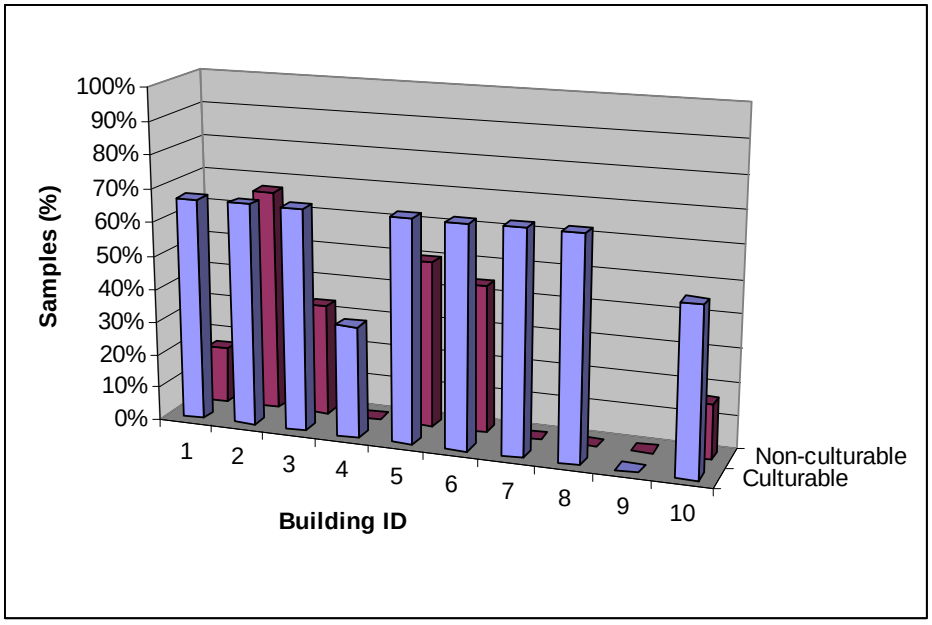


Figure N4. The percentage of outdoor culturable and non-culturable air samples in which *Cladosporium* was present as the predominant taxon.

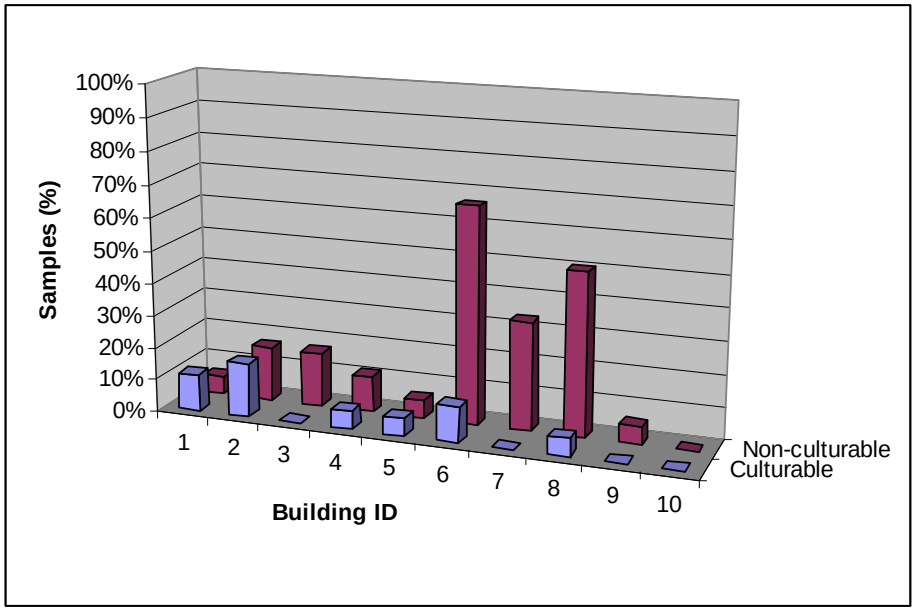


Figure N5. The percentage of indoor culturable and non-culturable air samples in which there was a predominant fungal taxon.

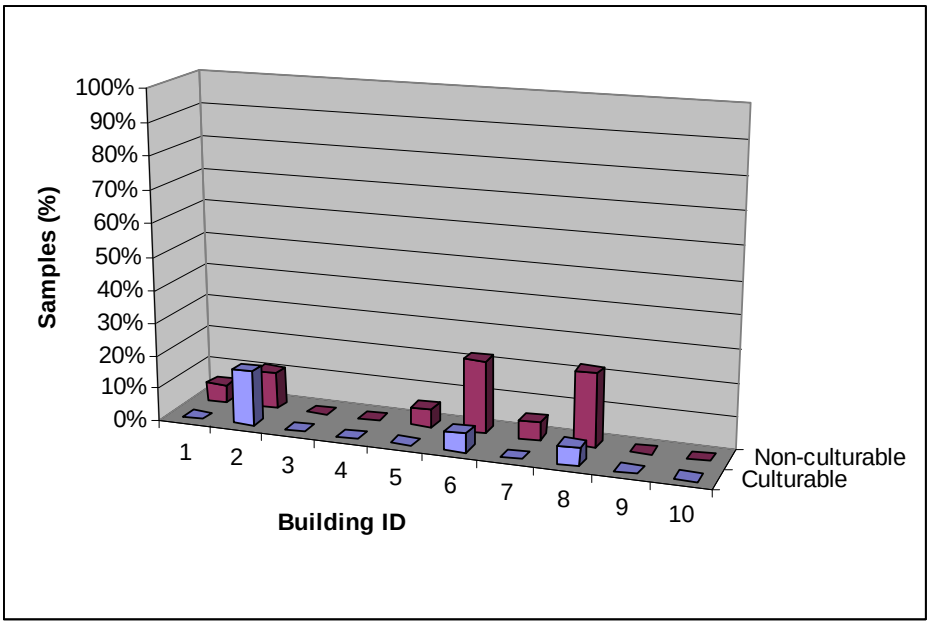


Figure N6. The percentage of indoor culturable and non-culturable air samples where *Cladosporium* was present as the predominant taxon.

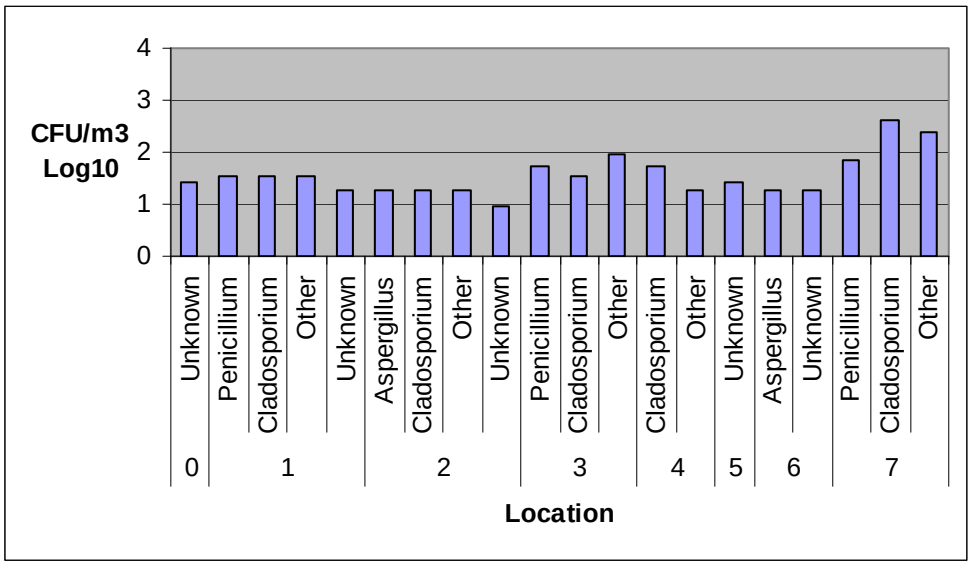


Figure N7. Building 1: Concentrations of selected airborne culturable fungi (i.e., *Aspergillus, Aureobasidium, Chaetomium, Cladosporium*, *Penicillium*, and *Trichoderma*) reported as the number of colony forming units per cubic meter of air (CFU/m3) in 6 indoor locations (1-6) and at the outdoor location in the morning (0) and the afternoon (7) sampling times (other = fungal genera not *Cladosporium*, *Penicillium*, *Aspergillus*, *Chaetomium, Trichoderma,* or *Aureobasidium*; unknown = fungi not identified).

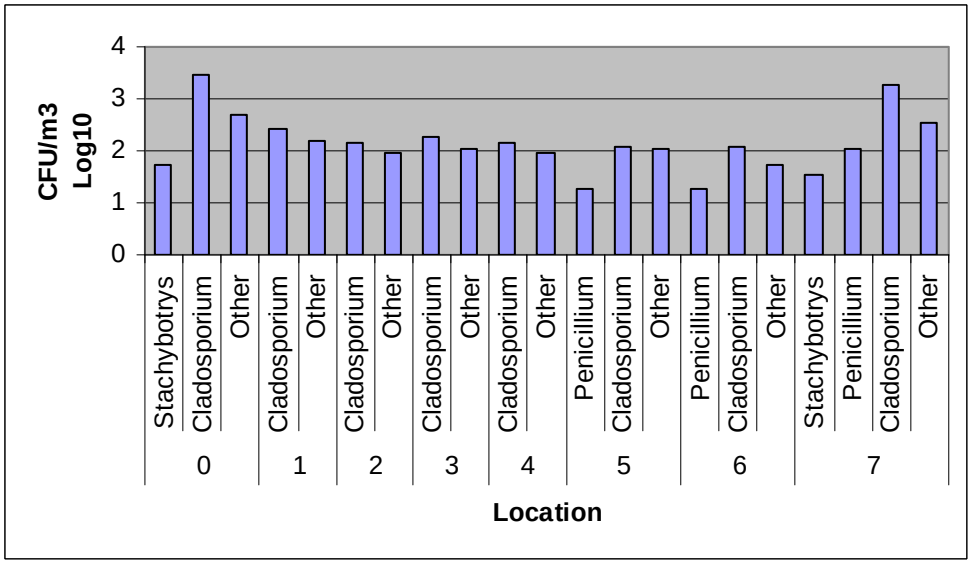


Figure N8. Building 2: Concentrations of selected airborne culturable fungi (i.e., *Aspergillus, Aureobasidium, Chaetomium, Cladosporium*, *Penicillium*, and *Trichoderma*) reported as the number of colony forming units per cubic meter of air (CFU/m3) in 6 indoor locations (1-6) and at the outdoor location in the morning (0) and the afternoon (7) sampling times (other = fungal genera not *Cladosporium*, *Penicillium*, *Aspergillus*, *Chaetomium, Trichoderma,* or *Aureobasidium*; unknown = fungi not identified).

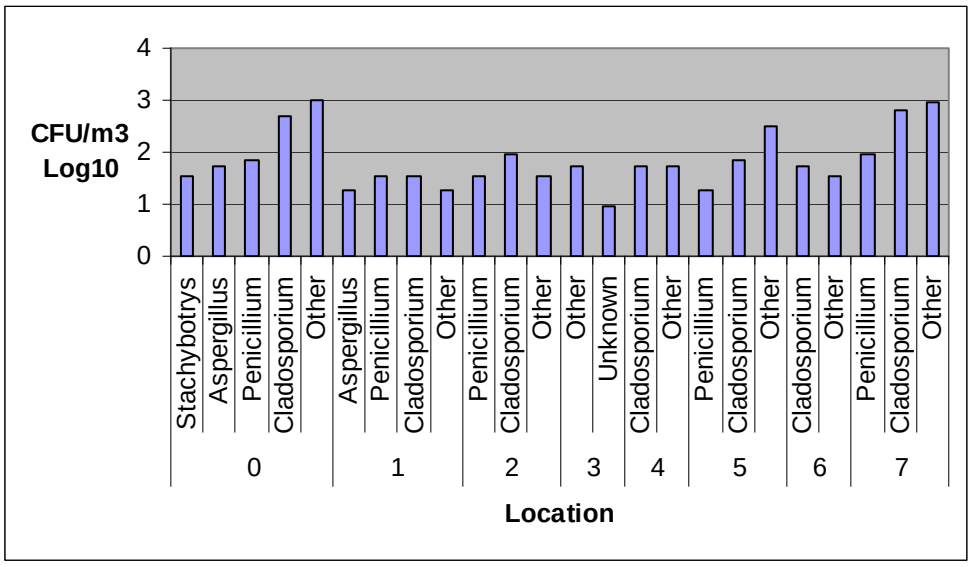


Figure N9. Building 3: Concentrations of selected airborne culturable fungi (i.e., *Aspergillus, Aureobasidium, Chaetomium, Cladosporium*, *Penicillium*, and *Trichoderma*) reported as the number of colony forming units per cubic meter of air (CFU/m3) in 6 indoor locations (1-6) and at the outdoor location in the morning (0) and the afternoon (7) sampling times (other = fungal genera not *Cladosporium*, *Penicillium*, *Aspergillus*, *Chaetomium, Trichoderma,* or *Aureobasidium*; unknown = fungi not identified).

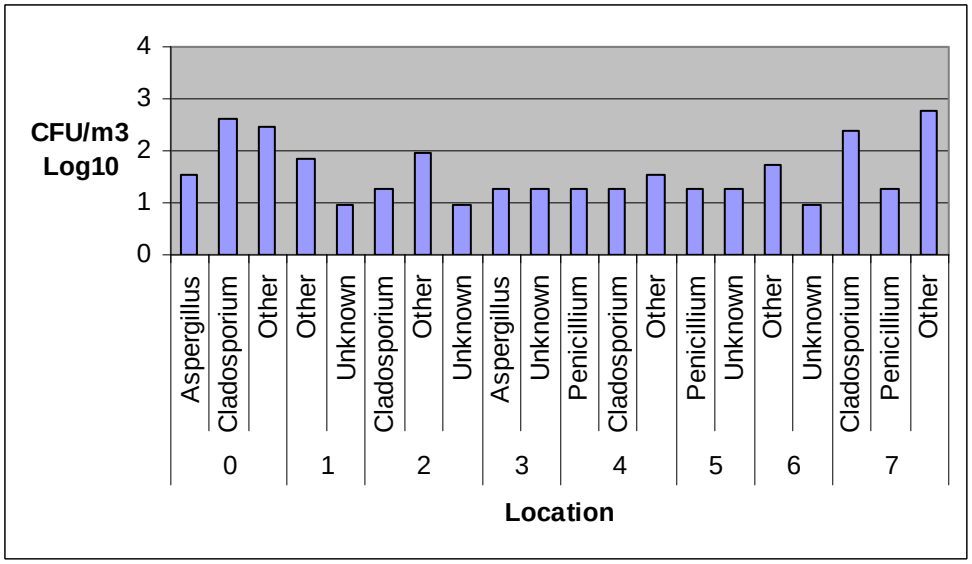


Figure N10. Building 4: Concentrations of selected airborne culturable fungi (i.e., *Aspergillus, Aureobasidium, Chaetomium, Cladosporium*, *Penicillium*, and *Trichoderma*) reported as the number of colony forming units per cubic meter of air (CFU/m3) in 6 indoor locations (1-6) and at the outdoor location in the morning (0) and the afternoon (7) sampling times (other = fungal genera not *Cladosporium*, *Penicillium*, *Aspergillus*, *Chaetomium, Trichoderma,* or *Aureobasidium*; unknown = fungi not identified).

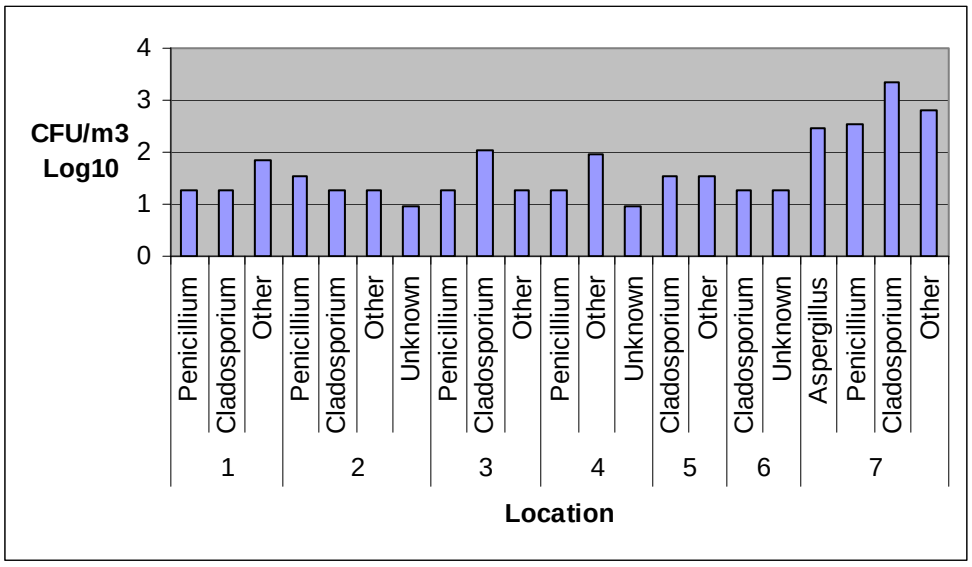


Figure N11. Building 5: Concentrations of selected airborne culturable fungi (i.e., *Aspergillus, Aureobasidium, Chaetomium, Cladosporium*, *Penicillium*, and *Trichoderma*) reported as the number of colony forming units per cubic meter of air (CFU/m3) in 6 indoor locations (1-6) and at the outdoor location in the morning (0) and the afternoon (7) sampling times (other = fungal genera not *Cladosporium*, *Penicillium*, *Aspergillus*, *Chaetomium, Trichoderma,* or *Aureobasidium*; unknown = fungi not identified).

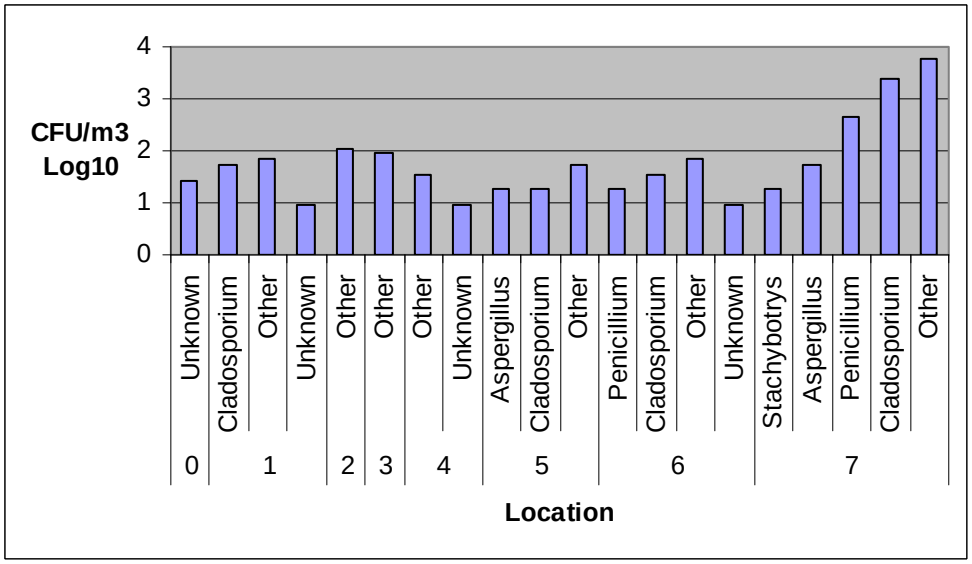


Figure N12. Building 6: Concentrations of selected airborne culturable fungi (i.e., *Aspergillus, Aureobasidium, Chaetomium, Cladosporium*, *Penicillium*, and *Trichoderma*) reported as the number of colony forming units per cubic meter of air (CFU/m3) in 6 indoor locations (1-6) and at the outdoor location in the morning (0) and the afternoon (7) sampling times (other = fungal genera not *Cladosporium*, *Penicillium*, *Aspergillus*, *Chaetomium, Trichoderma,* or *Aureobasidium*; unknown = fungi not identified).

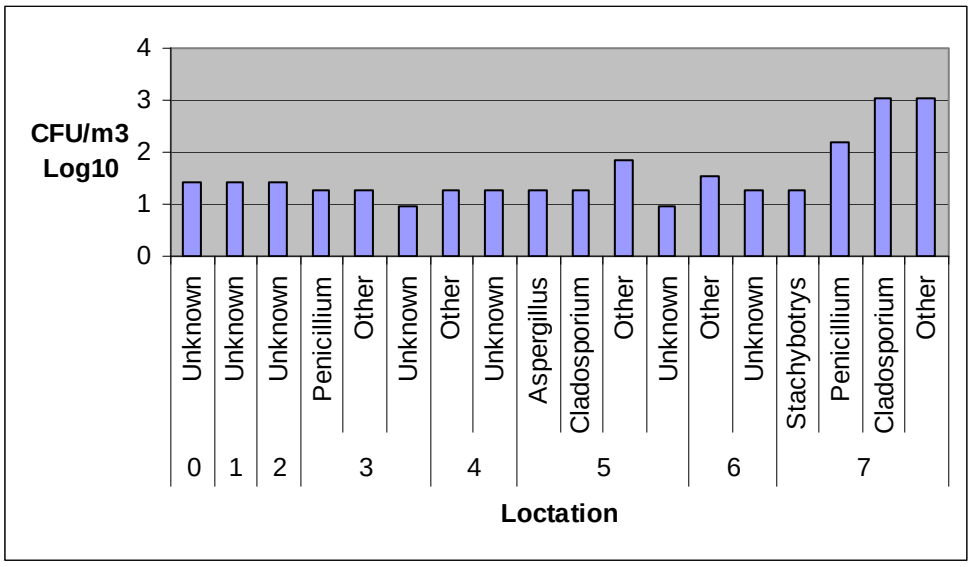


Figure N13. Building 7: Concentrations of selected airborne culturable fungi (i.e., *Aspergillus, Aureobasidium, Chaetomium, Cladosporium*, *Penicillium*, and *Trichoderma*) reported as the number of colony forming units per cubic meter of air (CFU/m3) in 6 indoor locations (1-6) and at the outdoor location in the morning (0) and the afternoon (7) sampling times (other = fungal genera not *Cladosporium*, *Penicillium*, *Aspergillus*, *Chaetomium, Trichoderma,* or *Aureobasidium*; unknown = fungi not identified).

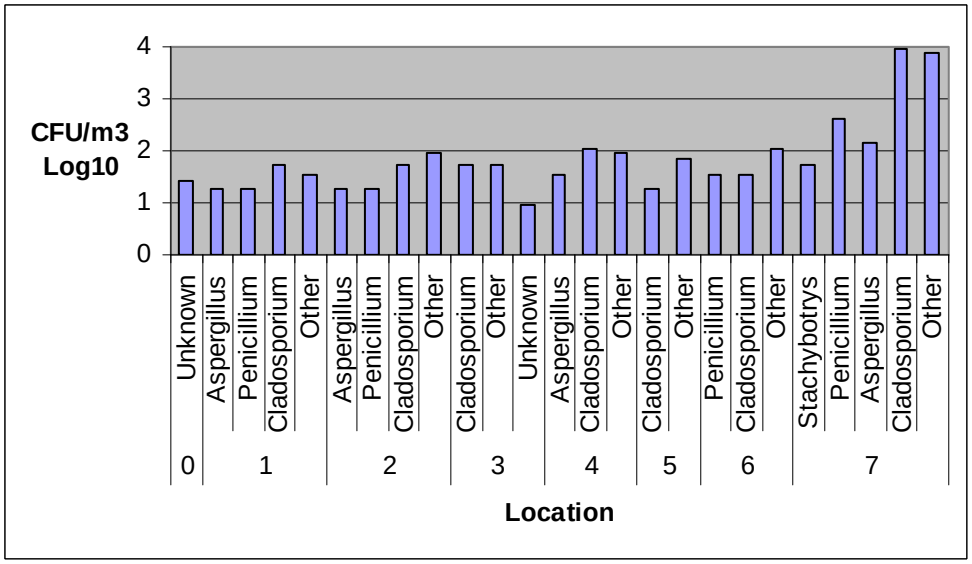


Figure N14. Building 8: Concentrations of selected airborne culturable fungi (i.e., *Aspergillus, Aureobasidium, Chaetomium, Cladosporium*, *Penicillium*, and *Trichoderma*) reported as the number of colony forming units per cubic meter of air (CFU/m3) in 6 indoor locations (1-6) and at the outdoor location in the morning (0) and the afternoon (7) sampling times (other = fungal genera not *Cladosporium*, *Penicillium*, *Aspergillus*, *Chaetomium, Trichoderma,* or *Aureobasidium*; unknown = fungi not identified).

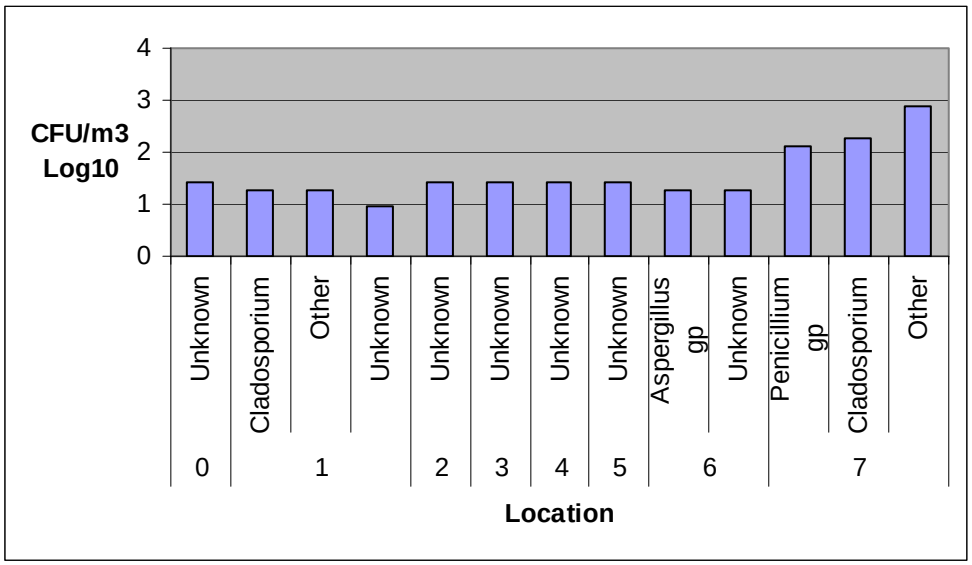


Figure N15. Building 9: Concentrations of selected airborne culturable fungi (i.e., *Aspergillus, Aureobasidium, Chaetomium, Cladosporium*, *Penicillium*, and *Trichoderma*) reported as the number of colony forming units per cubic meter of air (CFU/m3) in 6 indoor locations (1-6) and at the outdoor location in the morning (0) and the afternoon (7) sampling times (other = fungal genera not *Cladosporium*, *Penicillium*, *Aspergillus*, *Chaetomium, Trichoderma,* or *Aureobasidium*; unknown = fungi not identified).

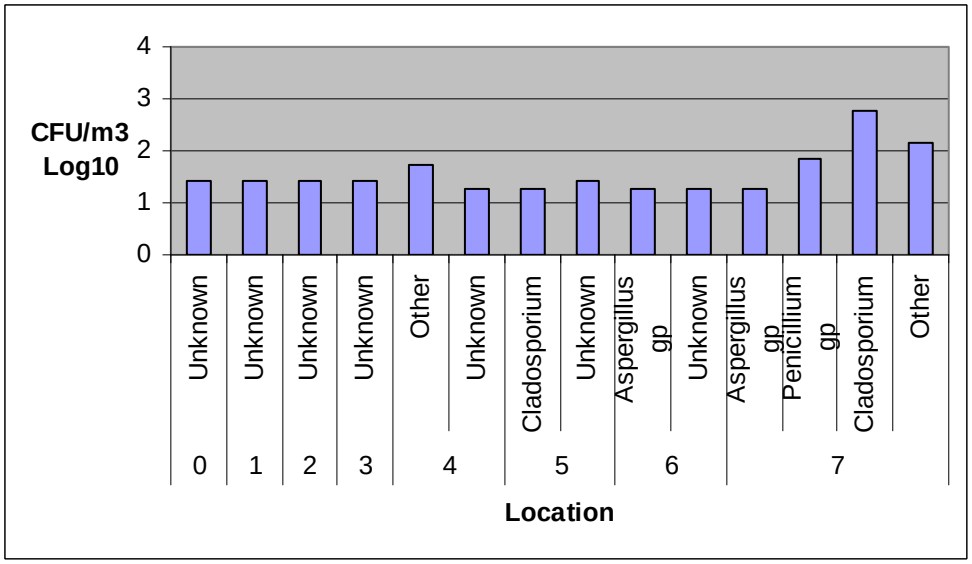


Figure N16. Building 10: Concentrations of selected airborne culturable fungi (i.e., *Aspergillus, Aureobasidium, Chaetomium, Cladosporium*, *Penicillium*, and *Trichoderma*) reported as the number of colony forming units per cubic meter of air (CFU/m3) in 6 indoor locations (1-6) and at the outdoor location in the morning (0) and the afternoon (7) sampling times (other = fungal genera not *Cladosporium*, *Penicillium*, *Aspergillus*, *Chaetomium, Trichoderma,* or *Aureobasidium*; unknown = fungi not identified).

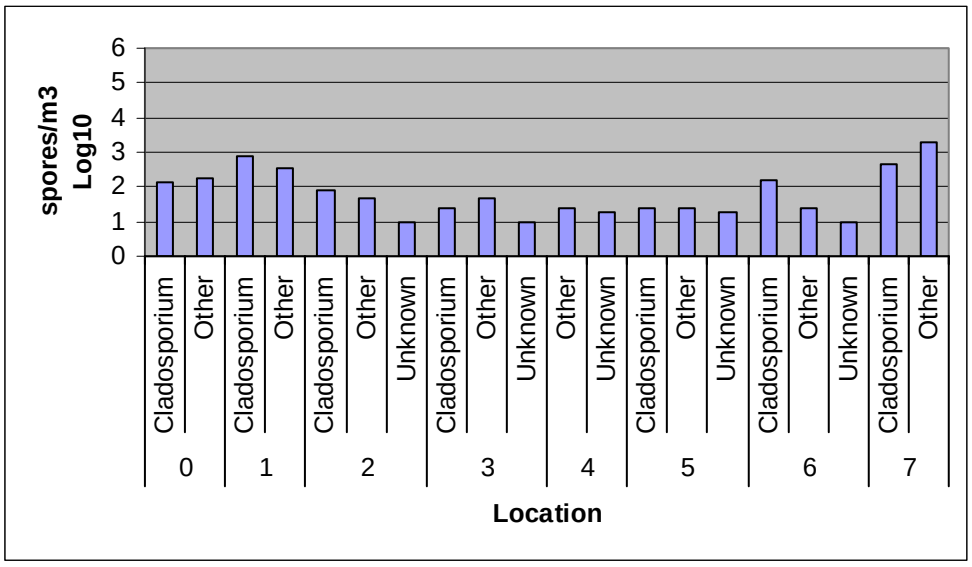


Figure N17. Building 1: Concentrations of selected fungal spores (i.e., Aspergillus/Penicillium, Aureobasidium, Chaeetomium, Cladosporium, and Trichoderma in the non-culturable air samples reported as the number of spores per cubic meter of air (spores/m3) in 6 indoor locations (1-6) and at the outdoor location in the morning (0) and the afternoon (7) sampling times (other = fungal genera not Aspergillus/Penicillium, Aureobasidium, Chaetomium, Cladosporium, or Trichoderma ; unknown = fungi not identified).

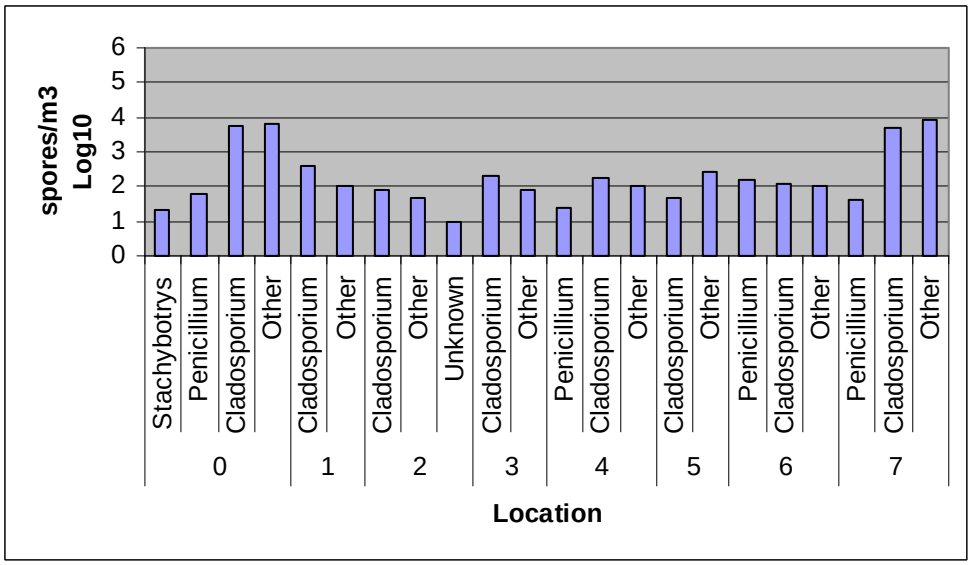


Figure N18. Building 2: Concentrations of selected fungal spores (i.e., *Aspergillus/Penicillium, Aureobasidium, Chaeetomium, Cladosporium*, and *Trichoderma* in the non-culturable air samples reported as the number of spores per cubic meter of air (spores/m3) in 6 indoor locations (1-6) and at the outdoor location in the morning (0) and the afternoon (7) sampling times (other = fungal genera not *Aspergillus/Penicillium, Aureobasidium, Chaetomium, Cladosporium*, or *Trichoderma* ; unknown = fungi not identified).

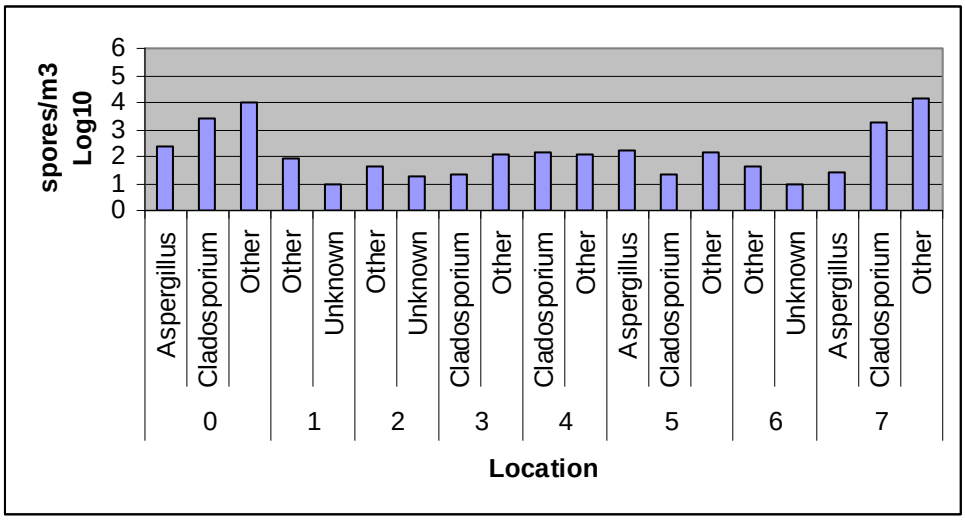


Figure N19. Building 3: Concentrations of selected fungal spores (i.e., *Aspergillus/Penicillium, Aureobasidium, Chaeetomium, Cladosporium*, and *Trichoderma* in the non-culturable air samples reported as the number of spores per cubic meter of air (spores/m3) in 6 indoor locations (1-6) and at the outdoor location in the morning (0) and the afternoon (7) sampling times (other = fungal genera not *Aspergillus/Penicillium, Aureobasidium, Chaetomium, Cladosporium*, or *Trichoderma*; unknown = fungi not identified).

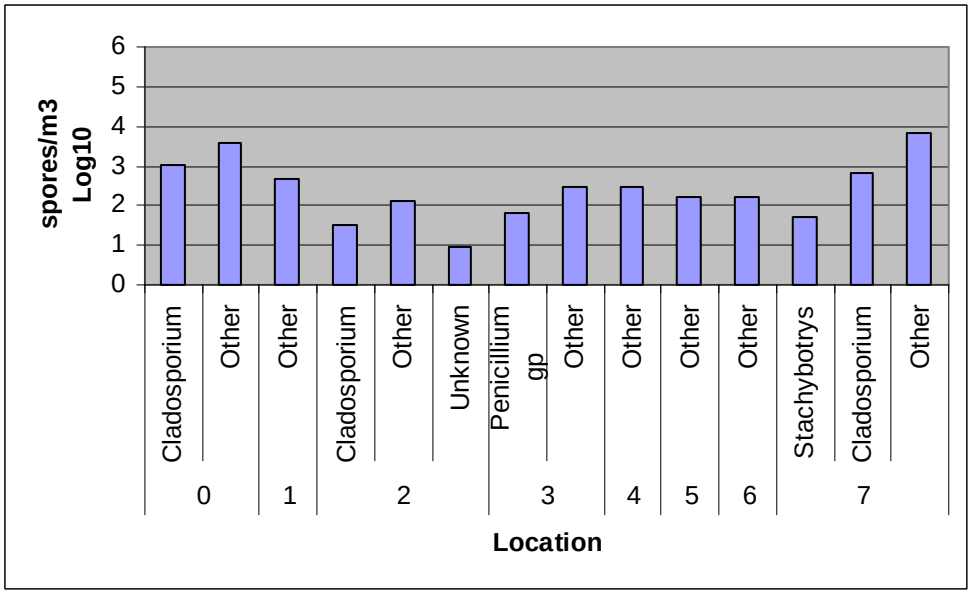


Figure N20. Building 4: Concentrations of selected fungal spores (i.e., *Aspergillus/Penicillium, Aureobasidium, Chaeetomium, Cladosporium*, and *Trichoderma* in the non-culturable air samples reported as the number of spores per cubic meter of air (spores/m3) in 6 indoor locations (1-6) and at the outdoor location in the morning (0) and the afternoon (7) sampling times (other = fungal genera not *Aspergillus/Penicillium, Aureobasidium, Chaetomium, Cladosporium*, or *Trichoderma*; unknown = fungi not identified).

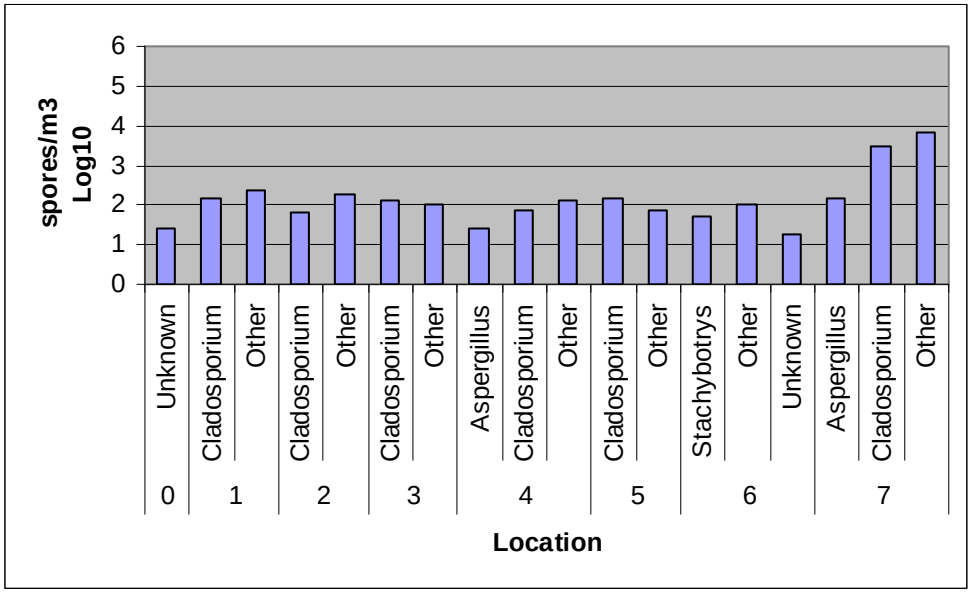


Figure N21. Building 5: Concentrations of selected fungal spores (i.e., *Aspergillus/Penicillium, Aureobasidium, Chaeetomium, Cladosporium*, and *Trichoderma* in the non-culturable air samples reported as the number of spores per cubic meter of air (spores/m3) in 6 indoor locations (1-6) and at the outdoor location in the morning (0) and the afternoon (7) sampling times (other = fungal genera not *Aspergillus/Penicillium, Aureobasidium, Chaetomium, Cladosporium*, or *Trichoderma*; unknown = fungi not identified).

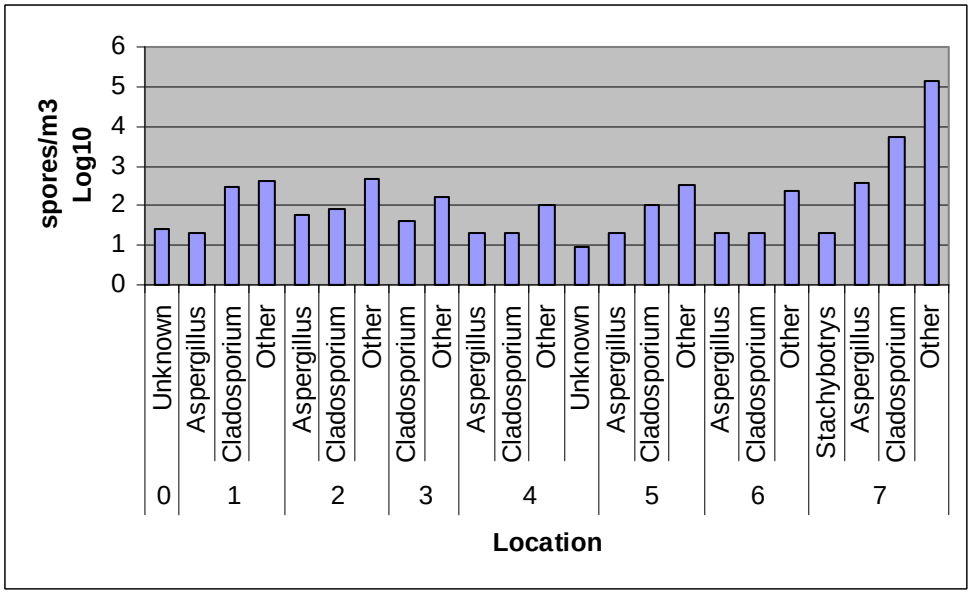


Figure N22. Building 6: Concentrations of selected fungal spores (i.e., *Aspergillus/Penicillium, Aureobasidium, Chaeetomium, Cladosporium*, and *Trichoderma* in the non-culturable air samples reported as the number of spores per cubic meter of air (spores/m3) in 6 indoor locations (1-6) and at the outdoor location in the morning (0) and the afternoon (7) sampling times (other = fungal genera not *Aspergillus/Penicillium, Aureobasidium, Chaetomium, Cladosporium*, or *Trichoderma*; unknown = fungi not identified).

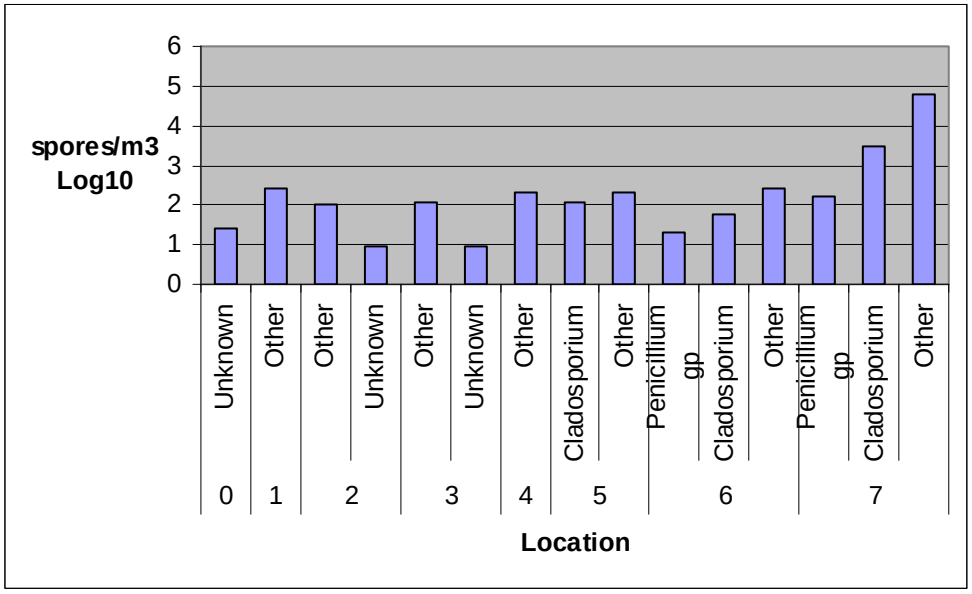


Figure N23. Building 7: Concentrations of selected fungal spores (i.e., *Aspergillus/Penicillium, Aureobasidium, Chaeetomium, Cladosporium*, and *Trichoderma* in the non-culturable air samples reported as the number of spores per cubic meter of air (spores/m3) in 6 indoor locations (1-6) and at the outdoor location in the morning (0) and the afternoon (7) sampling times (other = fungal genera not *Aspergillus/Penicillium, Aureobasidium, Chaetomium, Cladosporium*, or *Trichoderma*; unknown = fungi not identified).

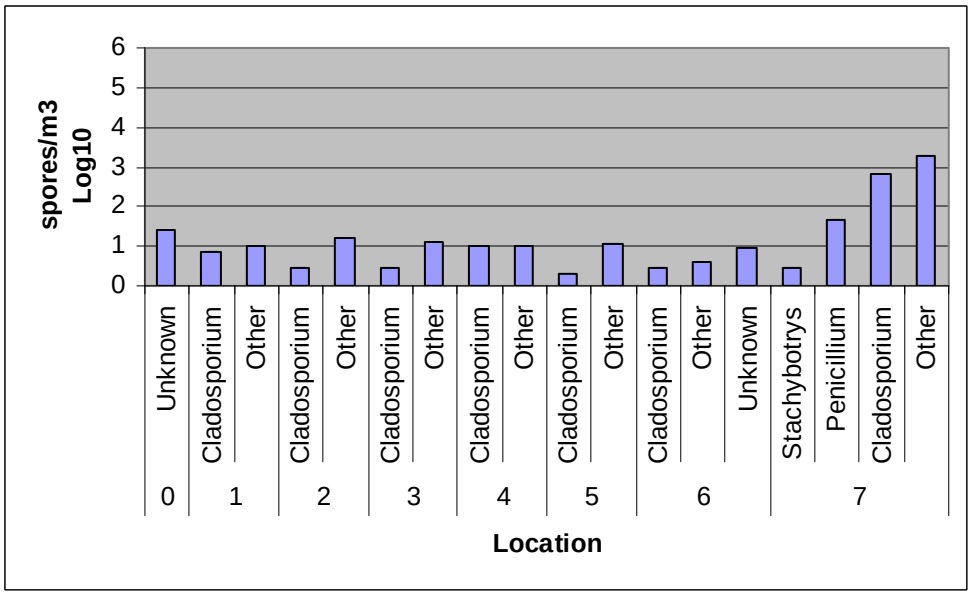


Figure N24. Building 8: Concentrations of selected fungal spores (i.e., *Aspergillus/Penicillium, Aureobasidium, Chaeetomium, Cladosporium*, and *Trichoderma* in the non-culturable air samples reported as the number of spores per cubic meter of air (spores/m3) in 6 indoor locations (1-6) and at the outdoor location in the morning (0) and the afternoon (7) sampling times (other = fungal genera not *Aspergillus/Penicillium, Aureobasidium, Chaetomium, Cladosporium*, or *Trichoderma*; unknown = fungi not identified).

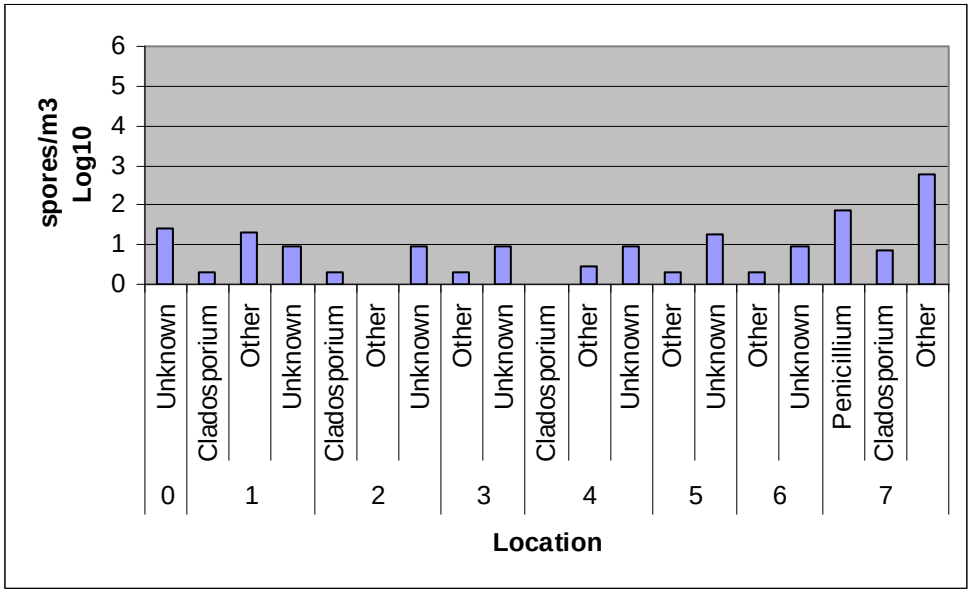


Figure N25. Building 9: Concentrations of selected fungal spores (i.e., *Aspergillus/Penicillium, Aureobasidium, Chaeetomium, Cladosporium*, and *Trichoderma* in the non-culturable air samples reported as the number of spores per cubic meter of air (spores/m3) in 6 indoor locations (1-6) and at the outdoor location in the morning (0) and the afternoon (7) sampling times (other = fungal genera not *Aspergillus/Penicillium, Aureobasidium, Chaetomium, Cladosporium*, or *Trichoderma*; unknown = fungi not identified).

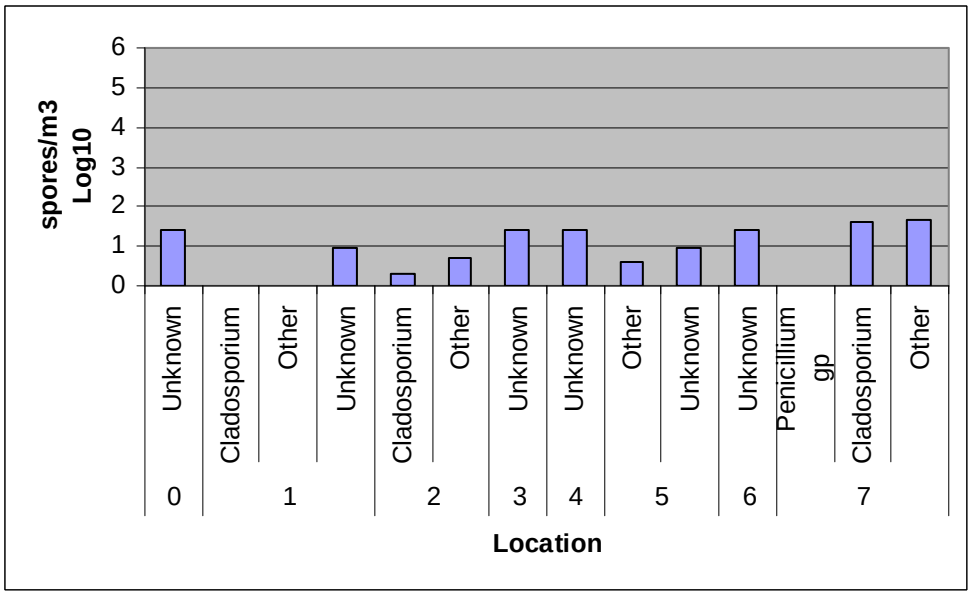


Figure N26. Building 10: Concentrations of selected fungal spores (i.e., *Aspergillus/Penicillium, Aureobasidium, Chaeetomium, Cladosporium*, and *Trichoderma* in the non-culturable air samples reported as the number of spores per cubic meter of air (spores/m3) in 6 indoor locations (1-6) and at the outdoor location in the morning (0) and the afternoon (7) sampling times (other = fungal genera not *Aspergillus/Penicillium, Aureobasidium, Chaetomium, Cladosporium*, or *Trichoderma*; unknown = fungi not identified).

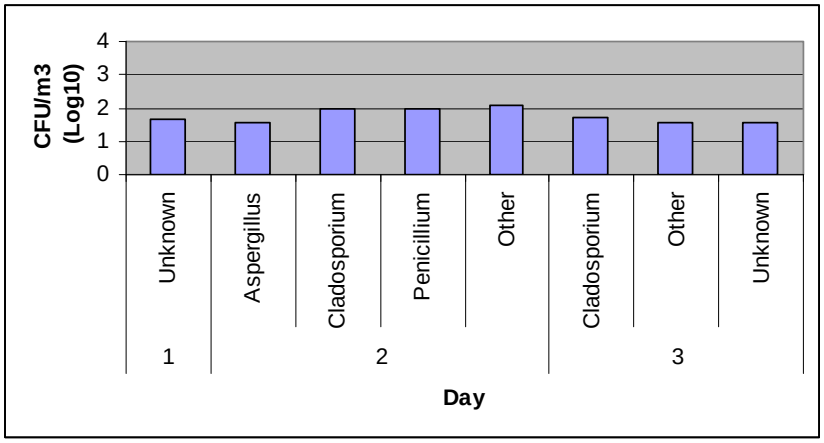


Figure N27. Building 1. Concentrations of selected airborne culturable fungi (i.e., *Aspergillus*, *Aureobasidium, Chaetomium, Cladosporium*, *Penicillium,* and *Trichoderma*) in indoor air samples reported as the $\log_{10}$ number of colony forming units per cubic meter of air (CFU/m3) during the three days of sampling (Day 1, 2 and 3) (other = fungal genera not *Aspergillus*, *Aureobasidium, Chaetomium, Cladosporium*, *Penicillium,* or *Trichoderma*,; unknown = fungi not identified).

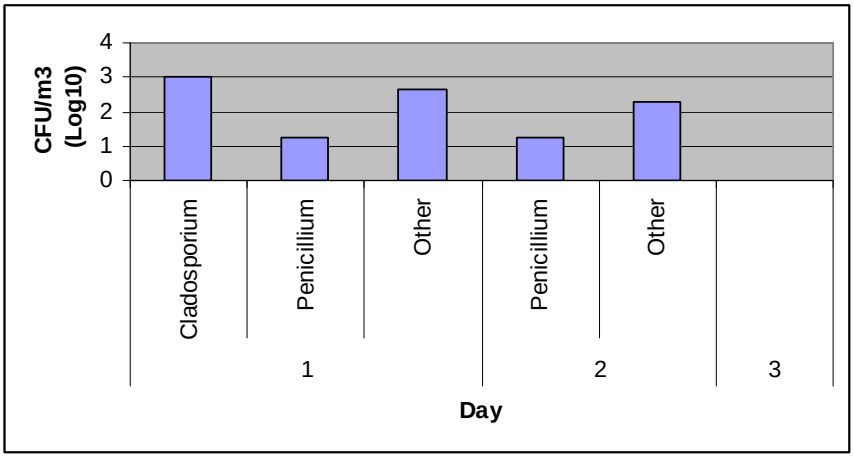


Figure N28. Building 2. Concentrations of selected airborne culturable fungi (i.e., *Aspergillus*, *Aureobasidium, Chaetomium, Cladosporium*, *Penicillium,* and *Trichoderma*) in indoor air samples reported as the $\log_{10}$ number of colony forming units per cubic meter of air (CFU/m3) during the three days of sampling (Day 1, 2 and 3) (other = fungal genera not *Aspergillus*, *Aureobasidium, Chaetomium, Cladosporium*, *Penicillium,* or *Trichoderma*,; unknown = fungi not identified).

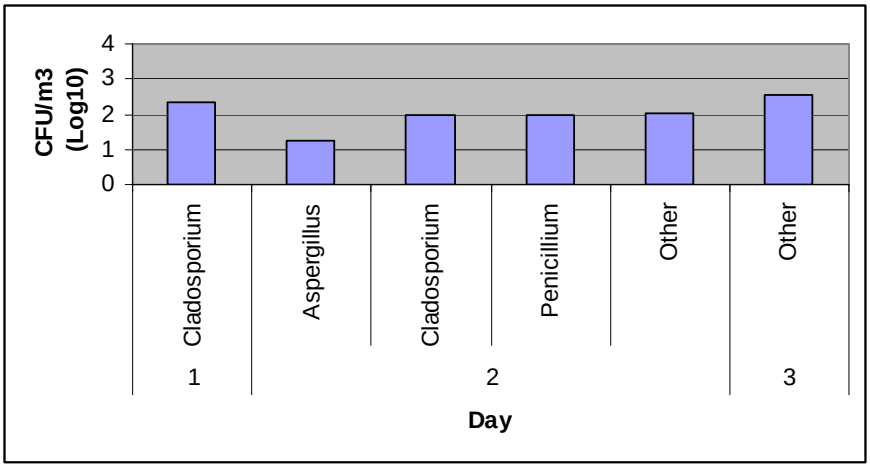


Figure N29. Building 3. Concentrations of selected airborne culturable fungi (i.e., *Aspergillus*, *Aureobasidium, Chaetomium, Cladosporium*, *Penicillium,* and *Trichoderma*) in indoor air samples reported as the log_{10} number of colony forming units per cubic meter of air (CFU/m3) during the three days of sampling (Day 1, 2 and 3) (other = fungal genera not *Aspergillus*, *Aureobasidium, Chaetomium, Cladosporium*, *Penicillium,* or *Trichoderma,*; unknown = fungi not identified).

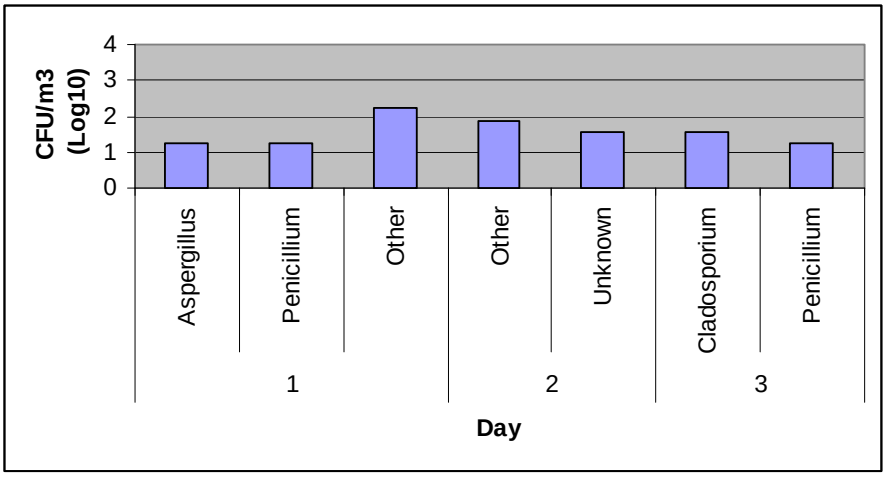


Figure N30. Building 4. Concentrations of selected airborne culturable fungi (i.e., *Aspergillus*, *Aureobasidium, Chaetomium, Cladosporium*, *Penicillium,* and *Trichoderma*) in indoor air samples reported as the log_{10} number of colony forming units per cubic meter of air (CFU/m3) during the three days of sampling (Day 1, 2 and 3) (other = fungal genera not *Aspergillus*, *Aureobasidium, Chaetomium, Cladosporium*, *Penicillium,* or *Trichoderma,*; unknown = fungi not identified).

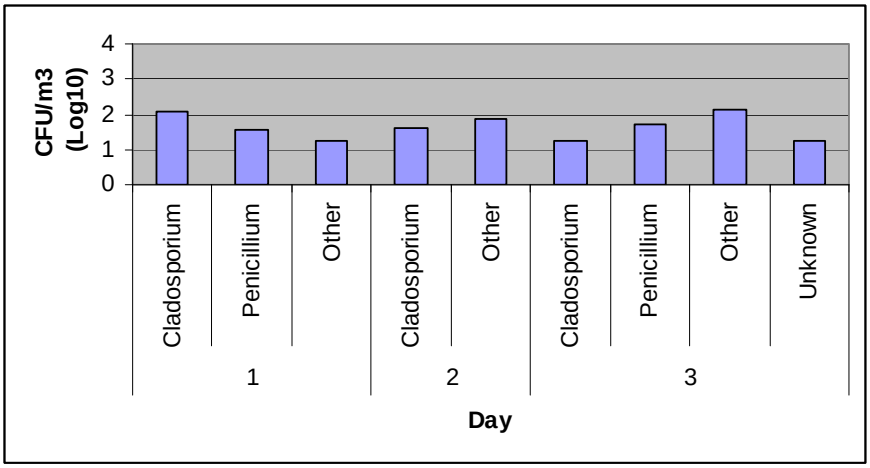


Figure N31. Building 5. Concentrations of selected airborne culturable fungi (i.e., *Aspergillus*, *Aureobasidium, Chaetomium, Cladosporium*, *Penicillium,* and *Trichoderma*) in indoor air samples reported as the $\log_{10}$ number of colony forming units per cubic meter of air (CFU/m3) during the three days of sampling (Day 1, 2 and 3) (other = fungal genera not *Aspergillus*, *Aureobasidium, Chaetomium, Cladosporium*, *Penicillium,* or *Trichoderma*,; unknown = fungi not identified).

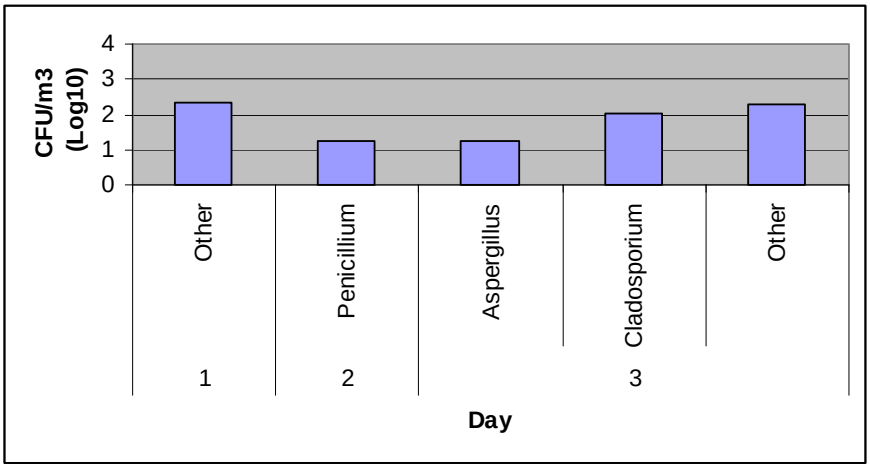


Figure N32. Building 6. Concentrations of selected airborne culturable fungi (i.e., *Aspergillus*, *Aureobasidium, Chaetomium, Cladosporium*, *Penicillium,* and *Trichoderma*) in indoor air samples reported as the $\log_{10}$ number of colony forming units per cubic meter of air (CFU/m3) during the three days of sampling (Day 1, 2 and 3) (other = fungal genera not *Aspergillus*, *Aureobasidium, Chaetomium, Cladosporium*, *Penicillium,* or *Trichoderma*,; unknown = fungi not identified).

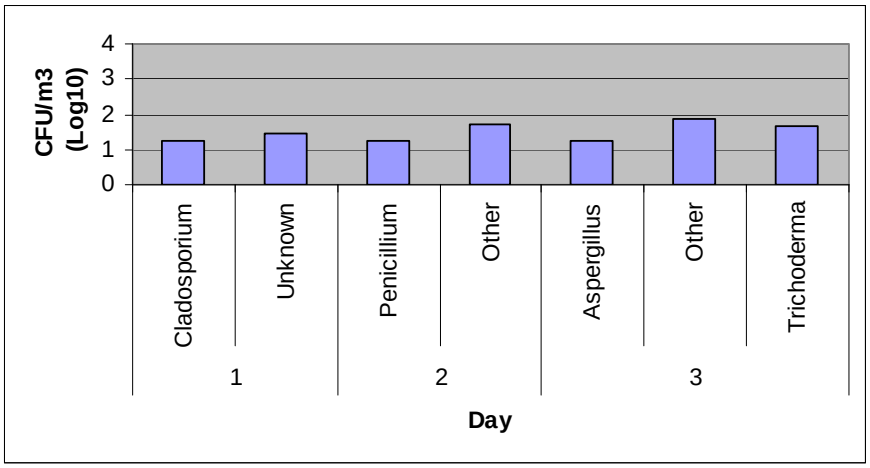


Figure N33. Building 7. Concentrations of selected airborne culturable fungi (i.e., *Aspergillus*, *Aureobasidium, Chaetomium, Cladosporium*, *Penicillium,* and *Trichoderma*) in indoor air samples reported as the log_{10} number of colony forming units per cubic meter of air (CFU/m3) during the three days of sampling (Day 1, 2 and 3) (other = fungal genera not *Aspergillus*, *Aureobasidium, Chaetomium, Cladosporium*, *Penicillium,* or *Trichoderma*,; unknown = fungi not identified).

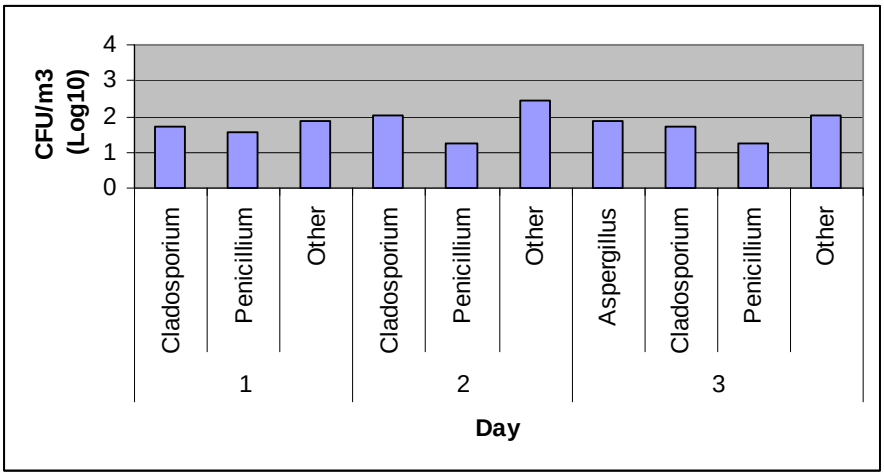


Figure N34. Building 8. Concentrations of selected airborne culturable fungi (i.e., *Aspergillus*, *Aureobasidium, Chaetomium, Cladosporium*, *Penicillium,* and *Trichoderma*) in indoor air samples reported as the log_{10} number of colony forming units per cubic meter of air (CFU/m3) during the three days of sampling (Day 1, 2 and 3) (other = fungal genera not *Aspergillus*, *Aureobasidium, Chaetomium, Cladosporium*, *Penicillium,* or *Trichoderma*,; unknown = fungi not identified).

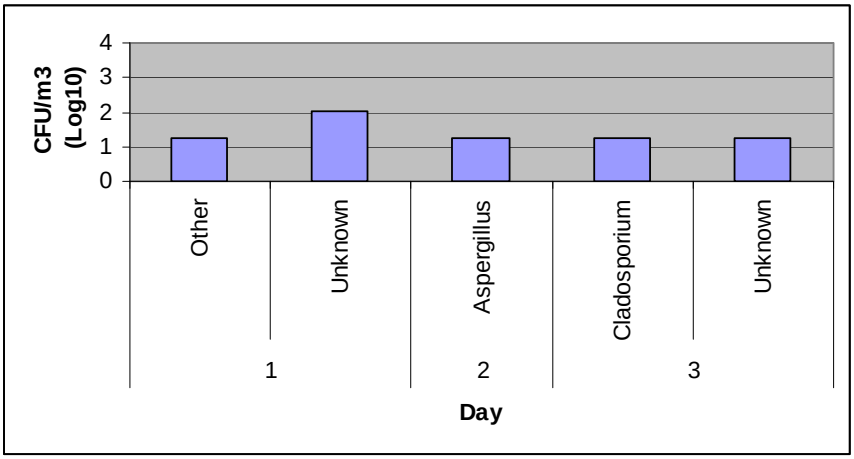


Figure N35. Building 9. Concentrations of selected airborne culturable fungi (i.e., *Aspergillus*, *Aureobasidium, Chaetomium, Cladosporium*, *Penicillium,* and *Trichoderma*) in indoor air samples reported as the $\log_{10}$ number of colony forming units per cubic meter of air (CFU/m3) during the three days of sampling (Day 1, 2 and 3) (other = fungal genera not *Aspergillus*, *Aureobasidium, Chaetomium, Cladosporium*, *Penicillium,* or *Trichoderma*,; unknown = fungi not identified).

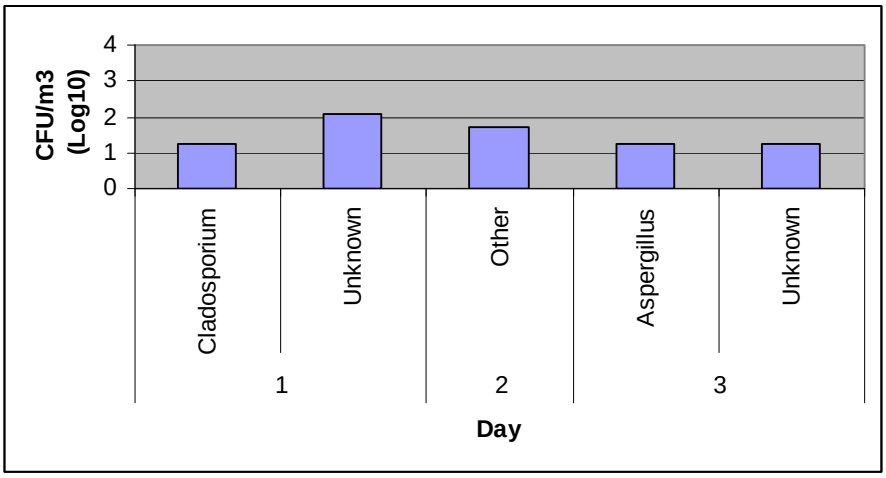


Figure N36. Building 10. Concentrations of selected airborne culturable fungi (i.e., *Aspergillus*, *Aureobasidium, Chaetomium, Cladosporium*, *Penicillium,* and *Trichoderma*) in indoor air samples reported as the $\log_{10}$ number of colony forming units per cubic meter of air (CFU/m3) during the three days of sampling (Day 1, 2 and 3) (other = fungal genera not *Aspergillus*, *Aureobasidium, Chaetomium, Cladosporium*, *Penicillium,* or *Trichoderma*,; unknown = fungi not identified).

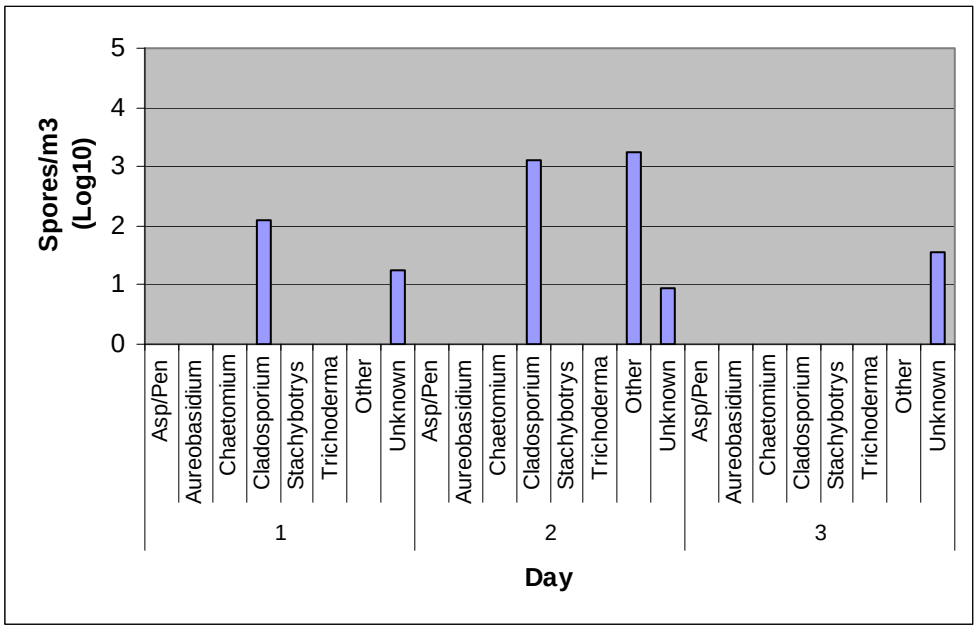


Figure N37. Building 1. Concentrations of fungal spores in the non-culturable indoor air samples reported as the $\log_{10}$ number of spores per cubic meter of air (spores/m3) during the three days of sampling (Day 1, 2 and 3) (Asp/Pen = *Aspergillus/Penicillium* spores; other = fungal genera not *Cladosporium*, *Aspergillus/ Penicillium, Chaetomium, Trichoderma,* or *Aureobasidium*; unknown = fungi not identified).

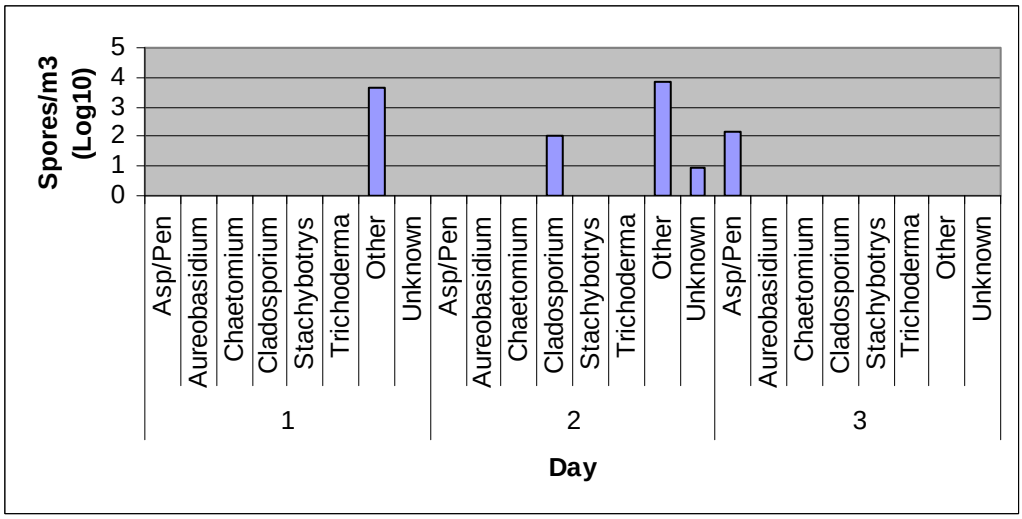


Figure N38. Building 2. Concentrations of fungal spores in the non-culturable indoor air samples reported as the $\log_{10}$ number of spores per cubic meter of air (spores/m3) during the three days of sampling (Day 1, 2 and 3) (Asp/Pen = *Aspergillus/Penicillium* spores; other = fungal genera not *Cladosporium*, *Aspergillus/ Penicillium, Chaetomium, Trichoderma,* or *Aureobasidium*; unknown = fungi not identified).

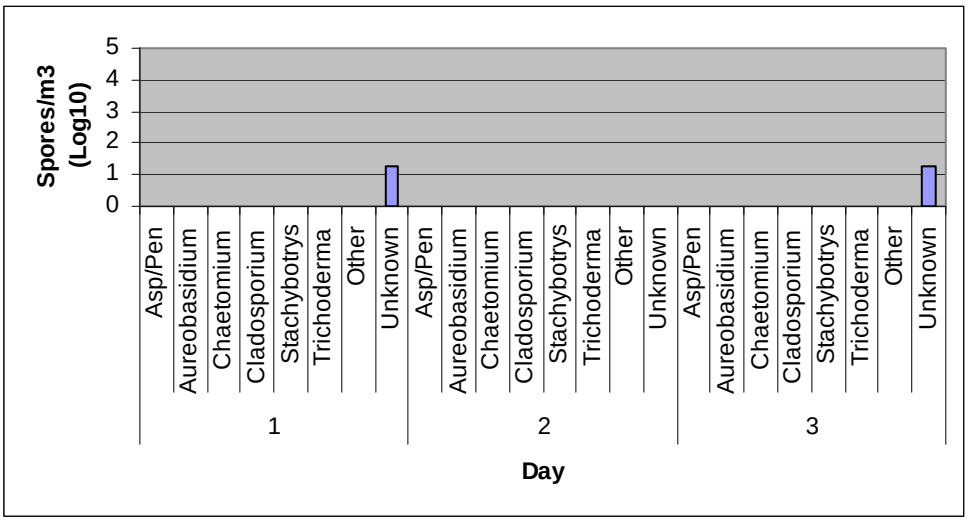


Figure N39. Building 3. Concentrations of fungal spores in the non-culturable indoor air samples reported as the $\log_{10}$ number of spores per cubic meter of air (spores/m3) during the three days of sampling (Day 1, 2 and 3) (Asp/Pen = *Aspergillus/Penicillium* spores; other = fungal genera not *Cladosporium*, *Aspergillus/ Penicillium, Chaetomium, Trichoderma,* or *Aureobasidium*; unknown = fungi not identified).

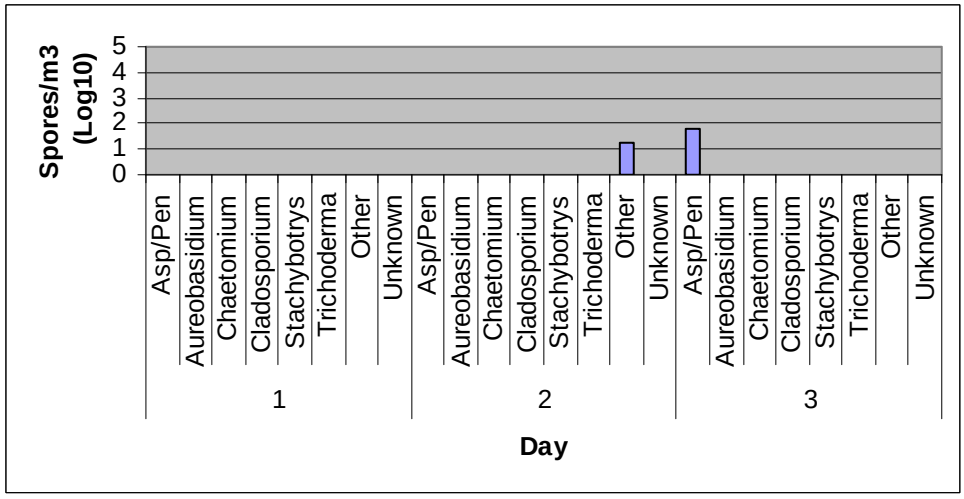


Figure N40. Building 4. Concentrations of fungal spores in the non-culturable indoor air samples reported as the $\log_{10}$ number of spores per cubic meter of air (spores/m3) during the three days of sampling (Day 1, 2 and 3) (Asp/Pen = *Aspergillus/Penicillium* spores; other = fungal genera not *Cladosporium*, *Aspergillus/ Penicillium, Chaetomium, Trichoderma,* or *Aureobasidium*; unknown = fungi not identified).

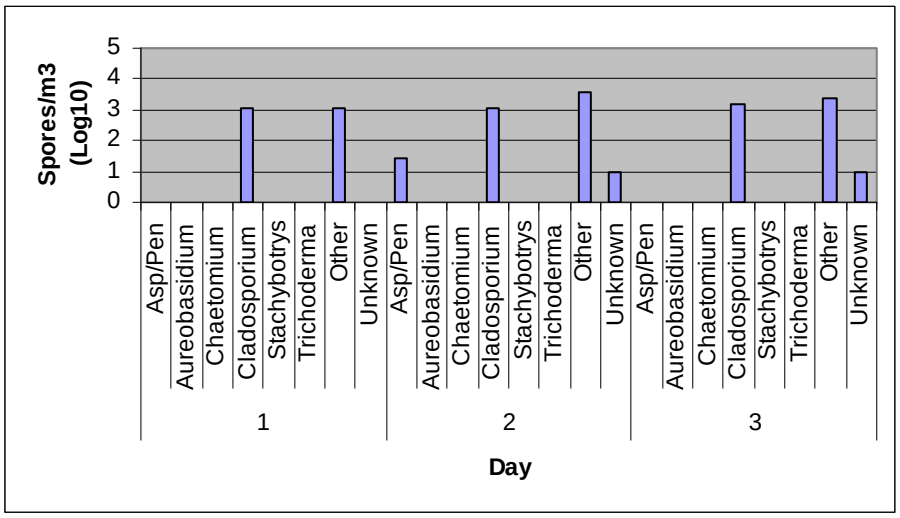


Figure N41. Building 5. Concentrations of fungal spores in the non-culturable indoor air samples reported as the $\log_{10}$ number of spores per cubic meter of air (spores/m3) during the three days of sampling (Day 1, 2 and 3) (Asp/Pen = *Aspergillus/Penicillium* spores; other = fungal genera not *Cladosporium*, *Aspergillus/ Penicillium, Chaetomium, Trichoderma,* or *Aureobasidium*; unknown = fungi not identified).

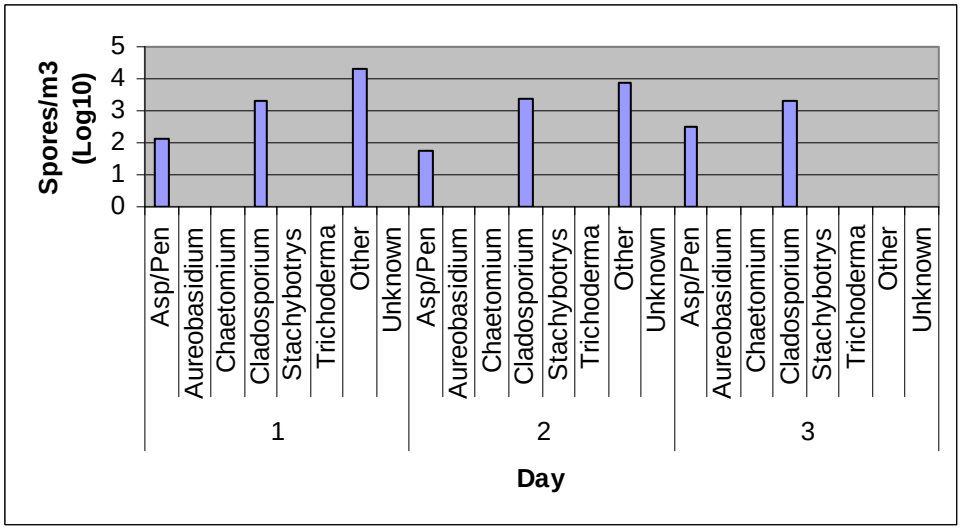


Figure N42. Building 6. Concentrations of fungal spores in the non-culturable indoor air samples reported as the $\log_{10}$ number of spores per cubic meter of air (spores/m3) during the three days of sampling (Day 1, 2 and 3) (Asp/Pen = *Aspergillus/Penicillium* spores; other = fungal genera not *Cladosporium*, *Aspergillus/ Penicillium, Chaetomium, Trichoderma,* or *Aureobasidium*; unknown = fungi not identified).

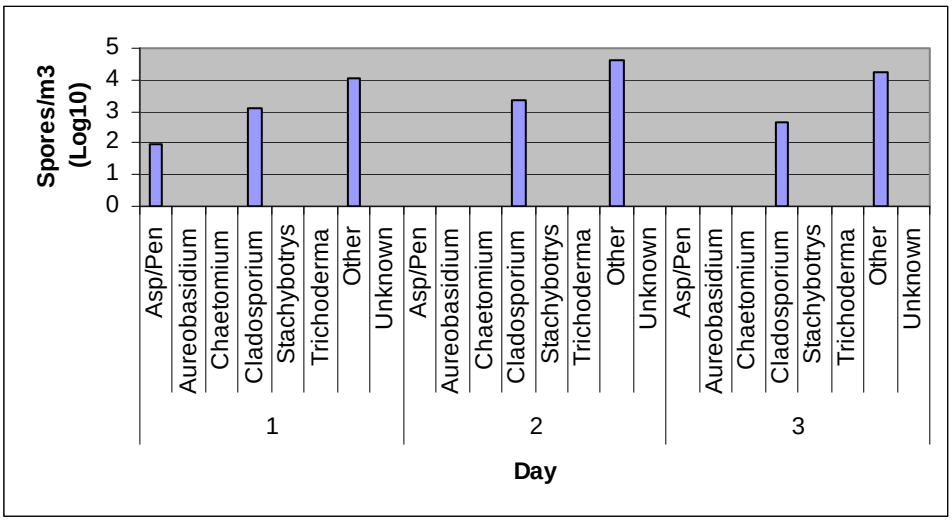


Figure N43. Building 7. Concentrations of fungal spores in the non-culturable indoor air samples reported as the $\log_{10}$ number of spores per cubic meter of air (spores/m3) during the three days of sampling (Day 1, 2 and 3) (Asp/Pen = *Aspergillus/Penicillium* spores; other = fungal genera not *Cladosporium*, *Aspergillus/ Penicillium, Chaetomium, Trichoderma,* or *Aureobasidium*; unknown = fungi not identified).

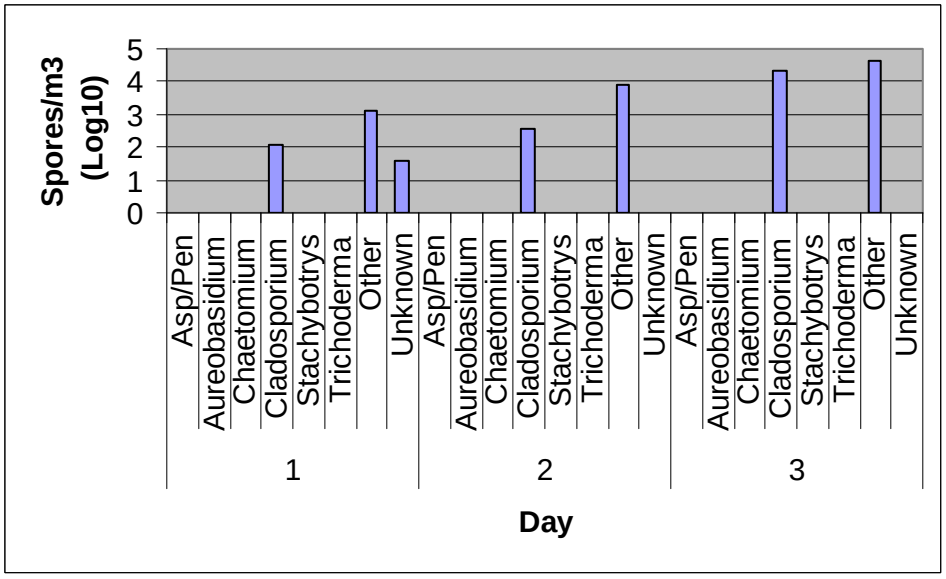


Figure N44. Building 8. Concentrations of fungal spores in the non-culturable indoor air samples reported as the $\log_{10}$ number of spores per cubic meter of air (spores/m3) during the three days of sampling (Day 1, 2 and 3) (Asp/Pen = *Aspergillus/Penicillium* spores; other = fungal genera not *Cladosporium*, *Aspergillus/ Penicillium, Chaetomium, Trichoderma,* or *Aureobasidium*; unknown = fungi not identified).

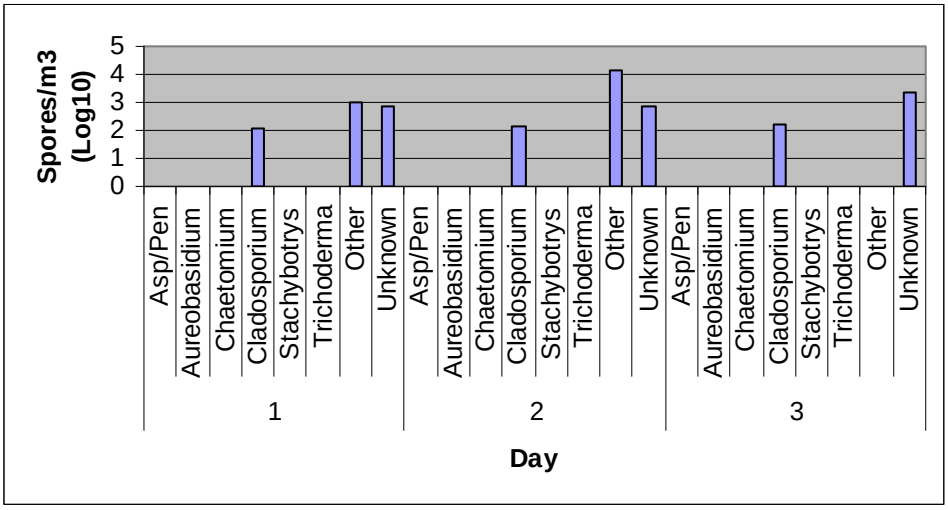


Figure N45. Building 9. Concentrations of fungal spores in the non-culturable indoor air samples reported as the $\log_{10}$ number of spores per cubic meter of air (spores/m3) during the three days of sampling (Day 1, 2 and 3) (Asp/Pen = *Aspergillus/Penicillium* spores; other = fungal genera not *Cladosporium*, *Aspergillus/ Penicillium, Chaetomium, Trichoderma,* or *Aureobasidium*; unknown = fungi not identified).

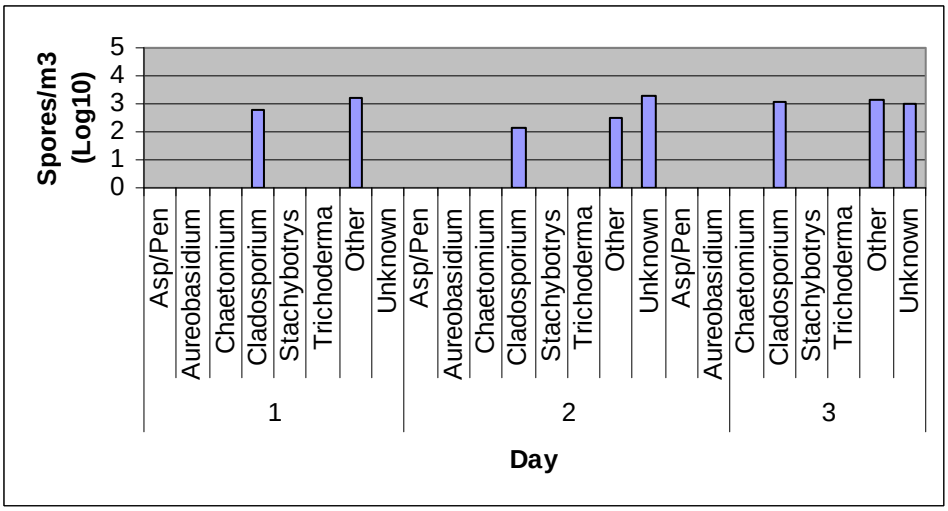


Figure N46. Building 10. Concentrations of fungal spores in the non-culturable indoor air samples reported as the $\log_{10}$ number of spores per cubic meter of air (spores/m3) during the three days of sampling (Day 1, 2 and 3) (Asp/Pen = *Aspergillus/Penicillium* spores; other = fungal genera not *Cladosporium*, *Aspergillus/ Penicillium, Chaetomium, Trichoderma,* or *Aureobasidium*; unknown = fungi not identified).

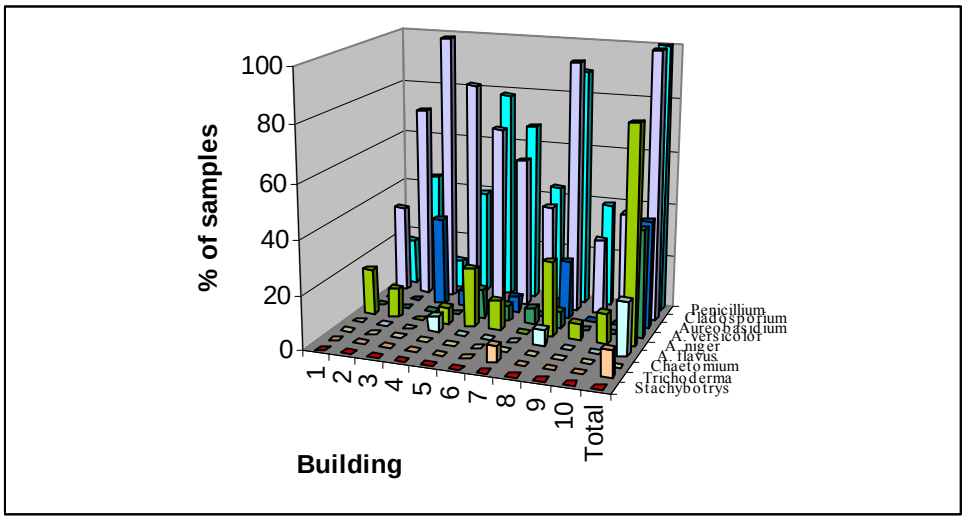


Figure N47. Presence of selected culturable fungi in vacuum samples.

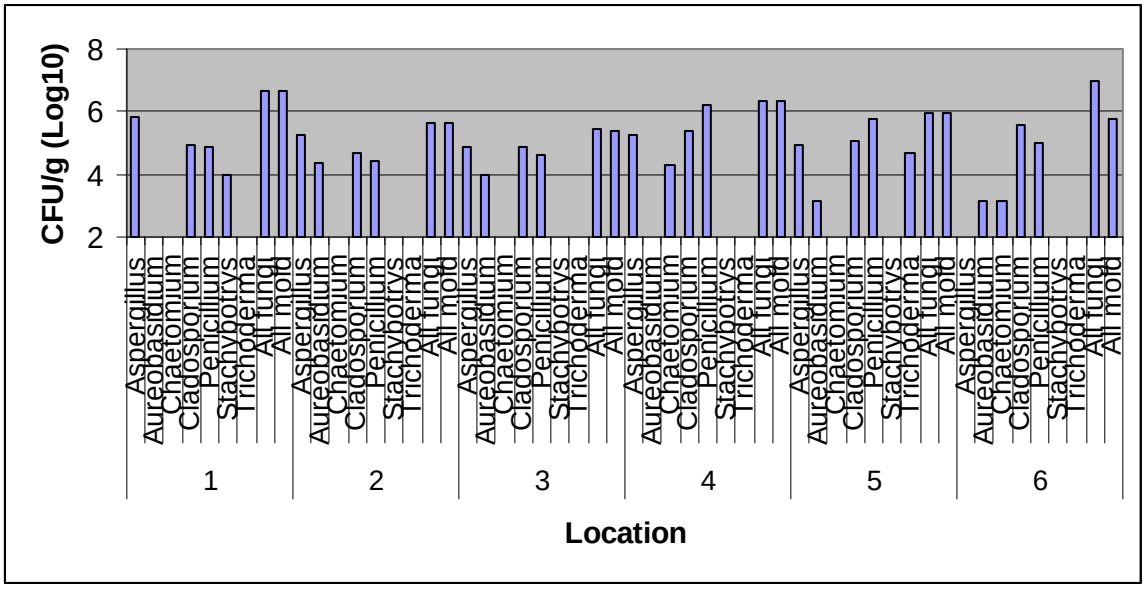


Figure N48. Building 1. Concentrations of *Aureobasidium*, *Chaetomium*, *Stachybotrys*, *Trichoderma* and the sum concentration of all culturable fungi (All fungi = mold + yeast+ non-sporulating mycelia) and culturable mold (All mold) in vacuum dust samples reported as the Log_{10} number of colony forming units per gram (CFU/g Log_{10}) in 6 indoor locations (1-6).

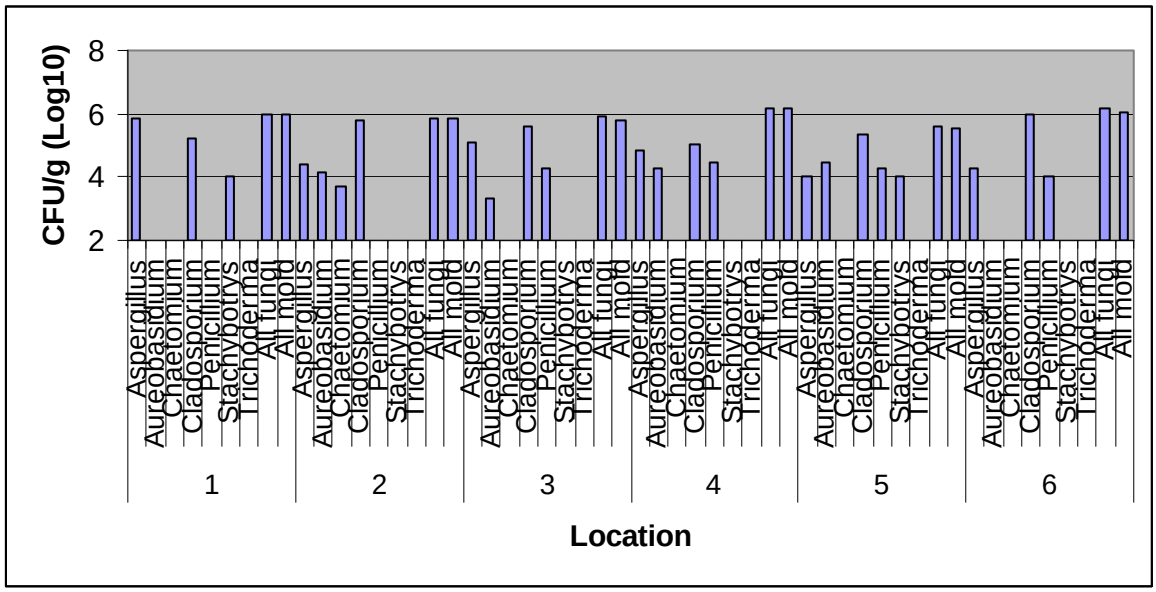


Figure N49. Building 2. Concentrations of *Aureobasidium*, *Chaetomium*, *Stachybotrys*, *Trichoderma* and the sum concentration of all culturable fungi (All fungi = mold + yeast+ non-sporulating mycelia) and culturable mold (All mold) in vacuum dust samples reported as the Log_{10} number of colony forming units per gram (CFU/g Log_{10}) in 6 indoor locations (1-6).

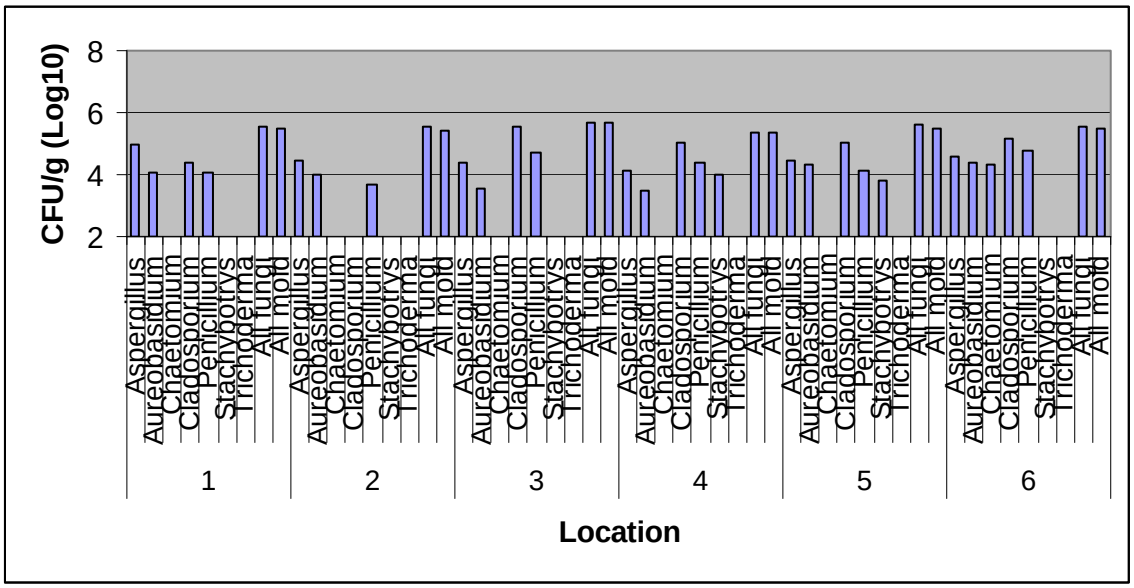


Figure N50. Building 3. Concentrations of *Aureobasidium*, *Chaetomium*, *Stachybotrys*, *Trichoderma* and the sum concentration of all culturable fungi (All fungi = mold + yeast+ non-sporulating mycelia) and culturable mold (All mold) in vacuum dust samples reported as the Log_{10} number of colony forming units per gram (CFU/g Log_{10}) in 6 indoor locations (1-6).

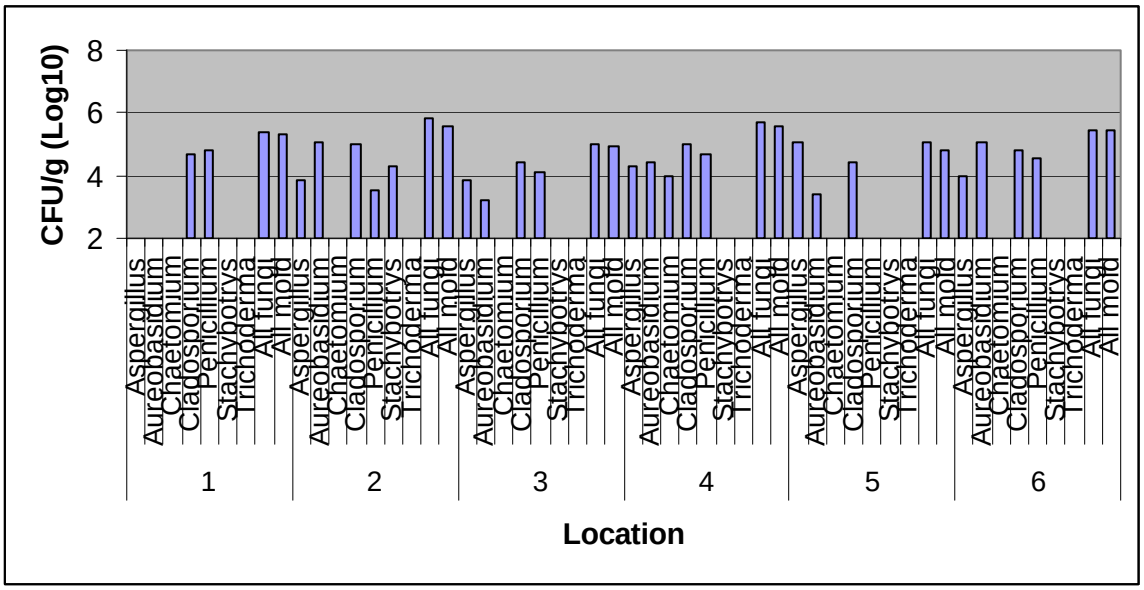


Figure N51. Building 4. Concentrations of *Aureobasidium*, *Chaetomium*, *Stachybotrys*, *Trichoderma* and the sum concentration of all culturable fungi (All fungi = mold + yeast+ non-sporulating mycelia) and culturable mold (All mold) in vacuum dust samples reported as the Log_{10} number of colony forming units per gram (CFU/g Log_{10}) in 6 indoor locations (1-6).

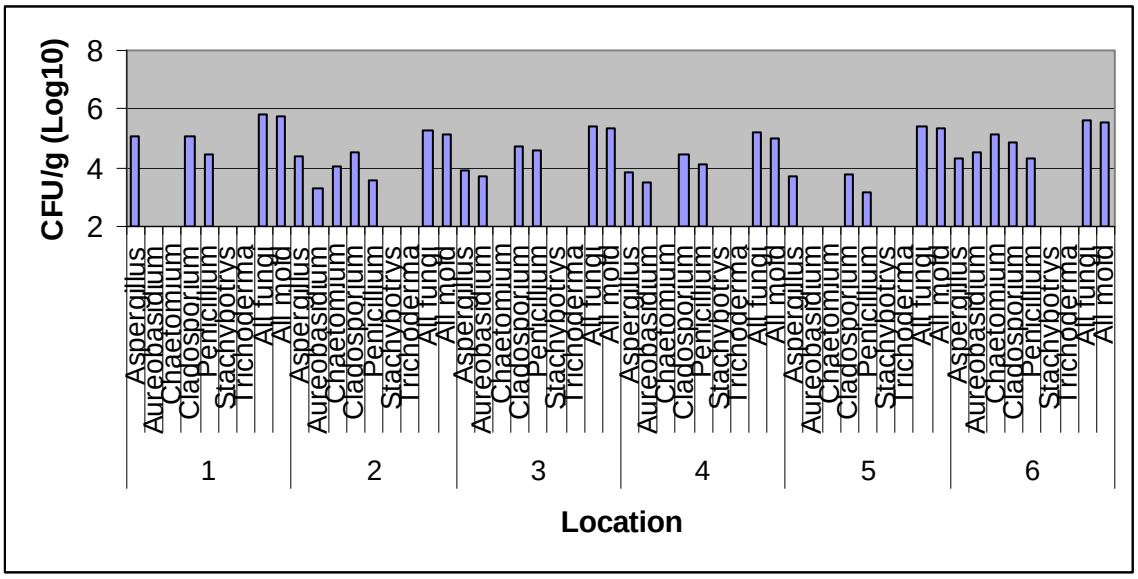


Figure N52. Building 5. Concentrations of *Aureobasidium*, *Chaetomium*, *Stachybotrys*, *Trichoderma* and the sum concentration of all culturable fungi (All fungi = mold + yeast+ non-sporulating mycelia) and culturable mold (All mold) in vacuum dust samples reported as the Log_{10} number of colony forming units per gram (CFU/g Log_{10}) in 6 indoor locations (1-6).

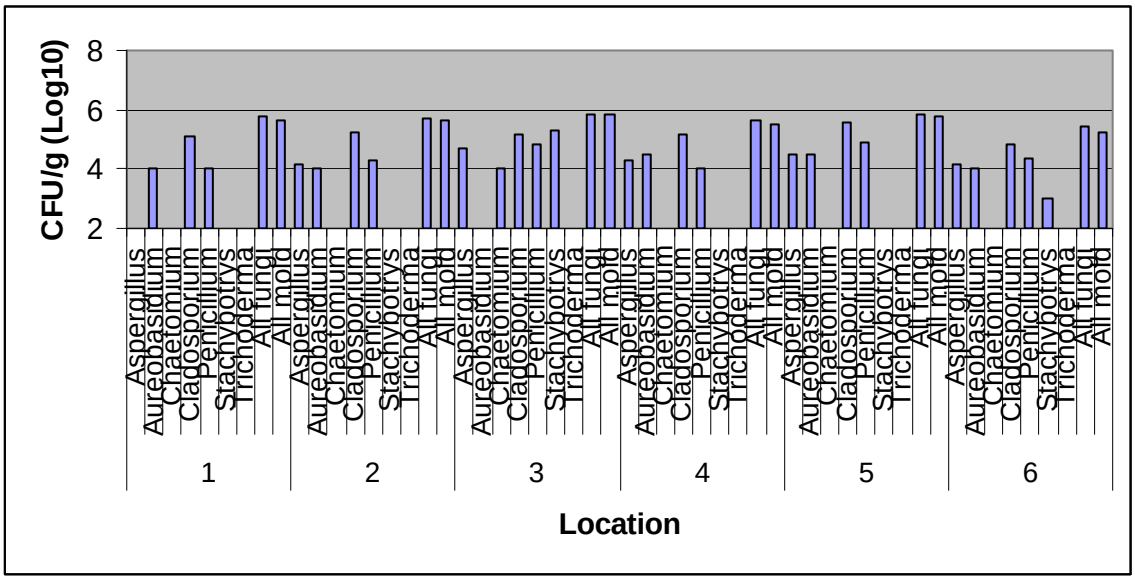


Figure N53. Building 6. Concentrations of *Aureobasidium*, *Chaetomium*, *Stachybotrys*, *Trichoderma* and the sum concentration of all culturable fungi (All fungi = mold + yeast+ non-sporulating mycelia) and culturable mold (All mold) in vacuum dust samples reported as the Log_{10} number of colony forming units per gram (CFU/g Log_{10}) in 6 indoor locations (1-6).

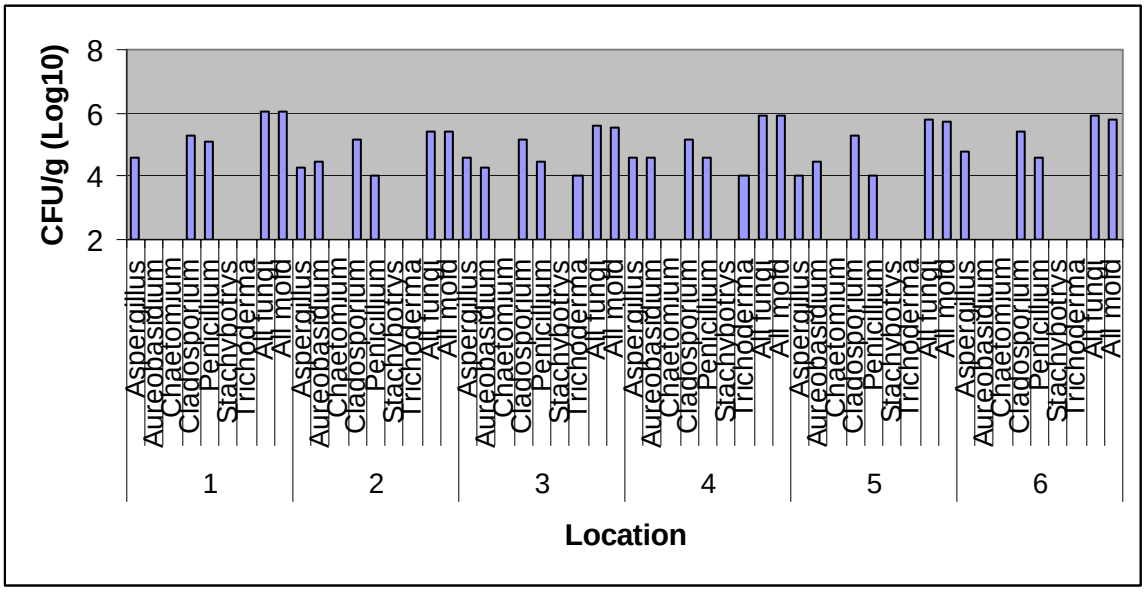


Figure N54. Building 7. . Concentrations of *Aureobasidium*, *Chaetomium*, *Stachybotrys*, *Trichoderma* and the sum concentration of all culturable fungi (All fungi = mold + yeast+ non-sporulating mycelia) and culturable mold (All mold) in vacuum dust samples reported as the Log_{10} number of colony forming units per gram (CFU/g Log_{10}) in 6 indoor locations (1-6).

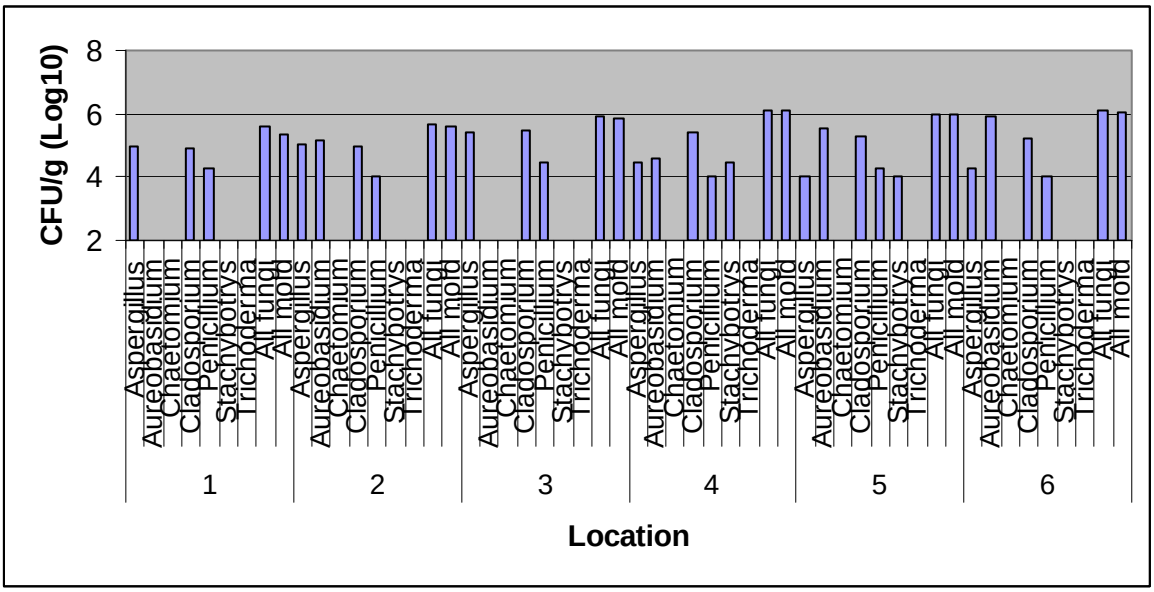


Figure N55. Building 8. Concentrations of *Aureobasidium*, *Chaetomium*, *Stachybotrys*, *Trichoderma* and the sum concentration of all culturable fungi (All fungi = mold + yeast+ non-sporulating mycelia) and culturable mold (All mold) in vacuum dust samples reported as the Log_{10} number of colony forming units per gram (CFU/g Log_{10}) in 6 indoor locations (1-6).

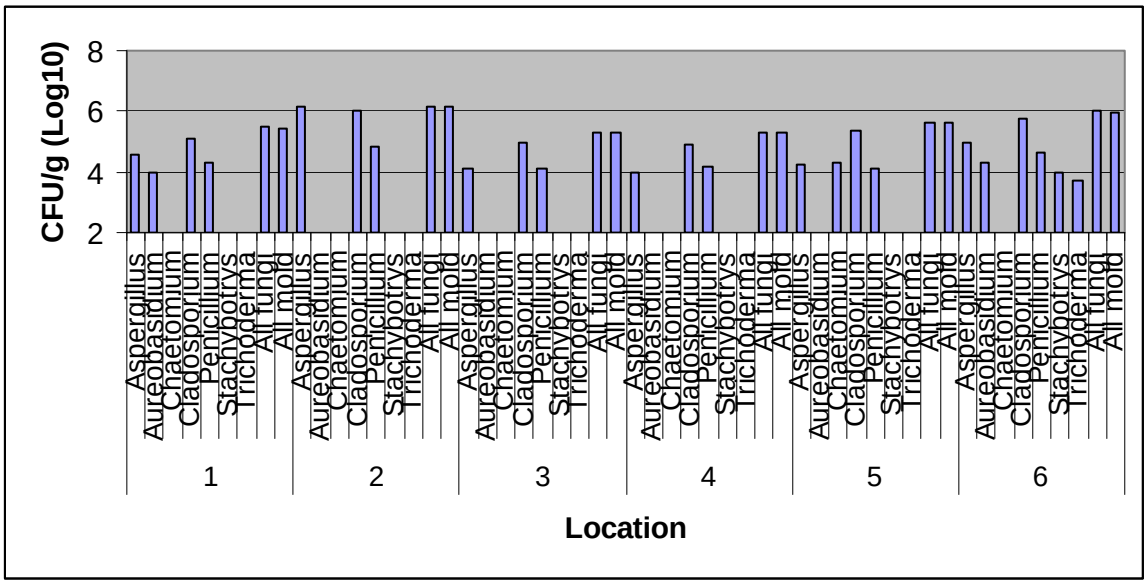


Figure N56. Building 9. Concentrations of *Aureobasidium*, *Chaetomium*, *Stachybotrys*, *Trichoderma* and the sum concentration of all culturable fungi (All fungi = mold + yeast+ non-sporulating mycelia) and culturable mold (All mold) in vacuum dust samples reported as the Log_{10} number of colony forming units per gram (CFU/g Log_{10}) in 6 indoor locations (1-6).

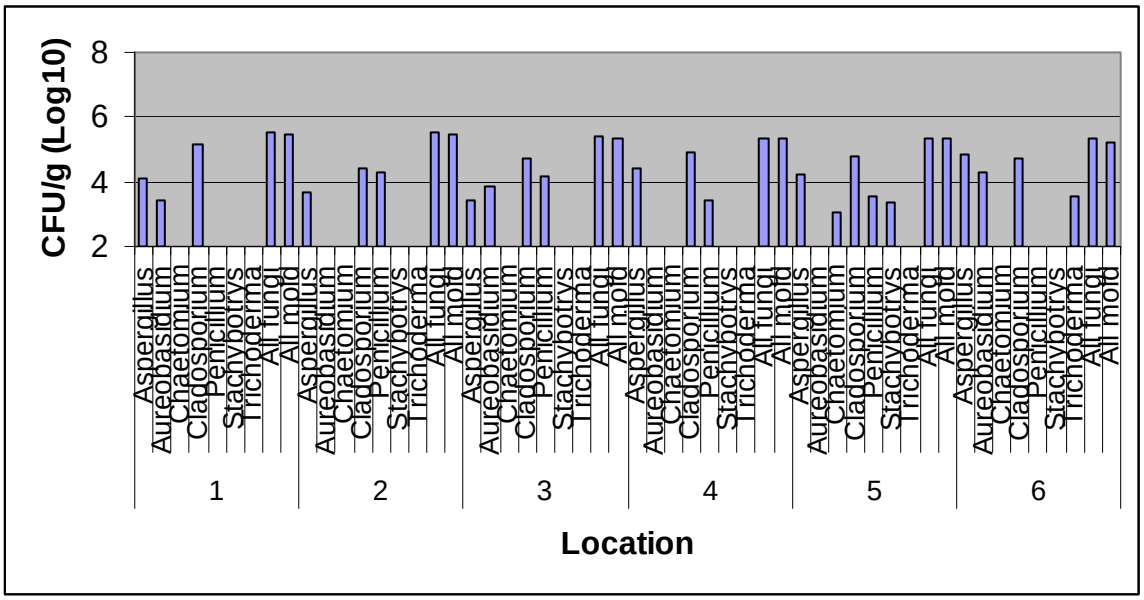


Figure N57. Building 10. Concentrations of *Aureobasidium*, *Chaetomium*, *Stachybotrys*, *Trichoderma* and the sum concentration of all culturable fungi (All fungi = mold + yeast+ non-sporulating mycelia) and culturable mold (All mold) in vacuum dust samples reported as the Log_{10} number of colony forming units per gram (CFU/g Log_{10}) in 6 indoor locations (1-6).

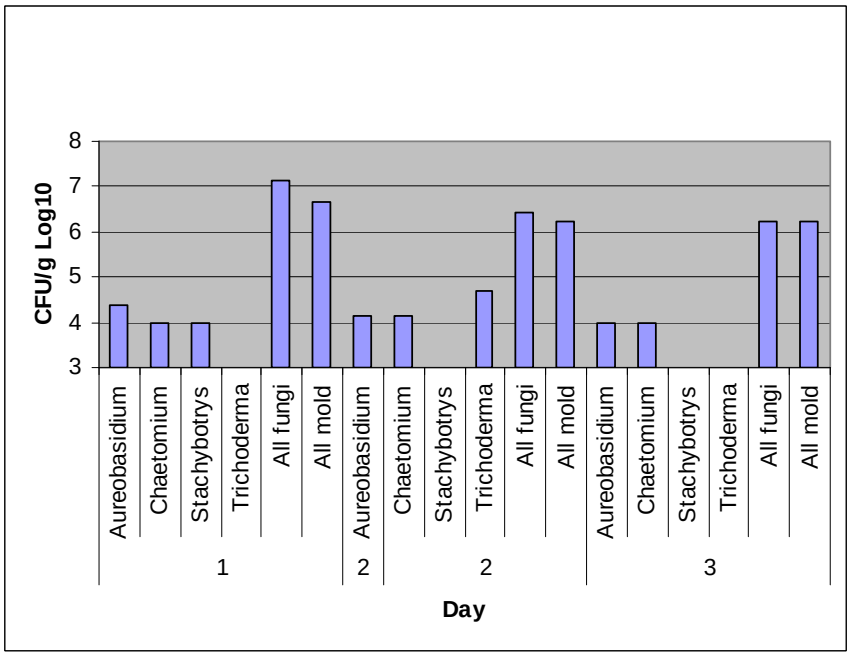


Figure N58. Building 1. Concentrations of *Aureobasidium*, *Chaetomium*, *Stachybotrys*, *Trichoderma* and the sum concentration of all culturable fungi (All fungi = mold + yeast+ non-sporulating mycelia) and culturable mold (All mold) in vacuum dust samples reported as the log_{10} number of colony forming units per gram (CFU/g Log_{10}) for the three sampling days (Day 1, 2, and 3).

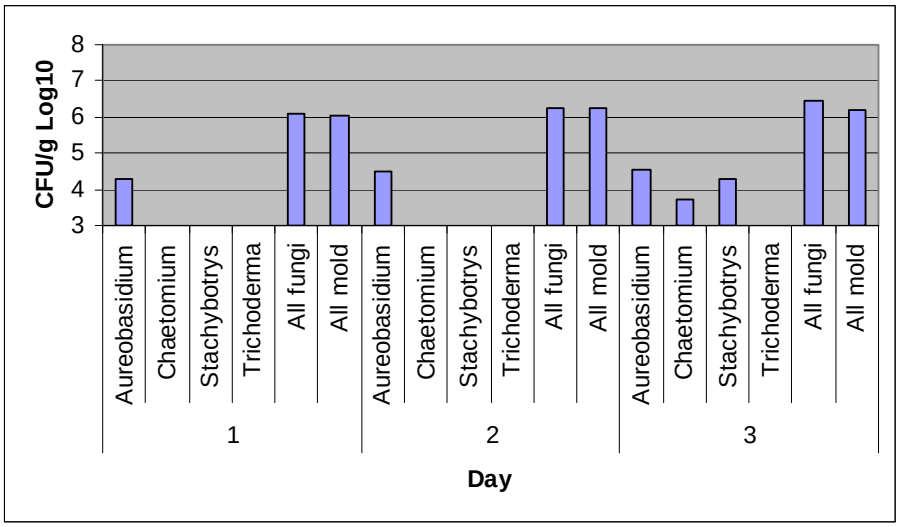


Figure N59. Building 2. Concentrations of *Aureobasidium*, *Chaetomium*, *Stachybotrys*, *Trichoderma* and the sum concentration of all culturable fungi (All fungi = mold + yeast+ non-sporulating mycelia) and culturable mold (All mold) in vacuum dust samples reported as the log_{10} number of colony forming units per gram (CFU/g Log_{10}) for the three sampling days (Day 1, 2, and 3).

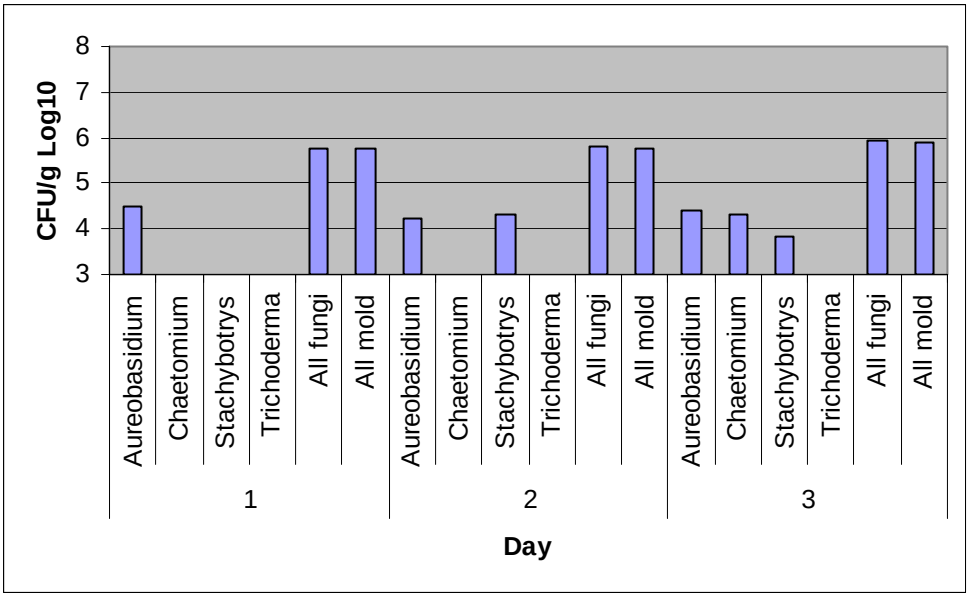


Figure N60. Building 3. Concentrations of *Aureobasidium*, *Chaetomium*, *Stachybotrys*, *Trichoderma* and the sum concentration of all culturable fungi (All fungi = mold + yeast+ non-sporulating mycelia) and culturable mold (All mold) in vacuum dust samples reported as the Log_{10} number of colony forming units per gram (CFU/g Log_{10}) for the three sampling days (Day 1, 2, and 3).

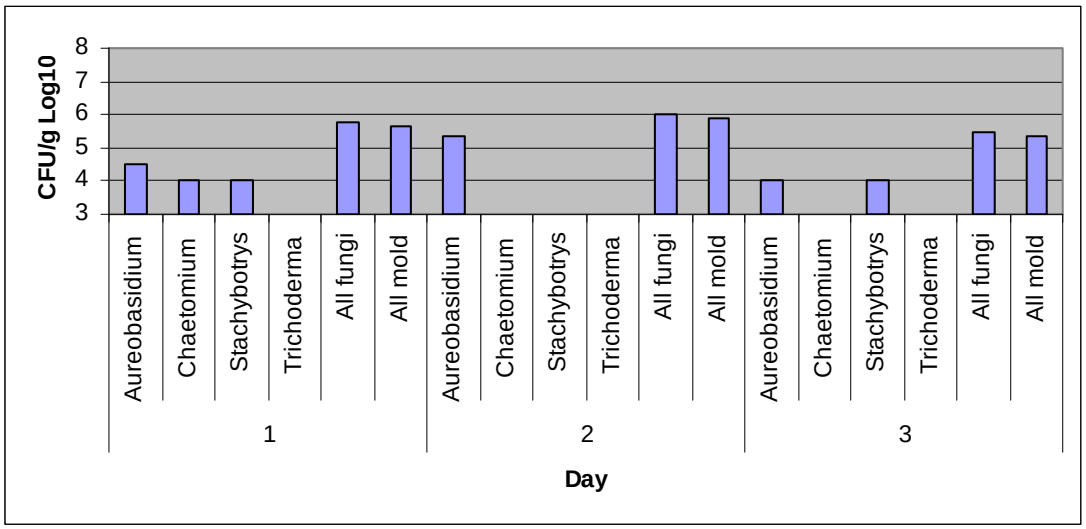


Figure N61. Building 4. Concentrations of *Aureobasidium*, *Chaetomium*, *Stachybotrys*, *Trichoderma* and the sum concentration of all culturable fungi (All fungi = mold + yeast+ non-sporulating mycelia) and culturable mold (All mold) in vacuum dust samples reported as the Log_{10} number of colony forming units per gram (CFU/g Log_{10}) for the three sampling days (Day 1, 2, and 3).

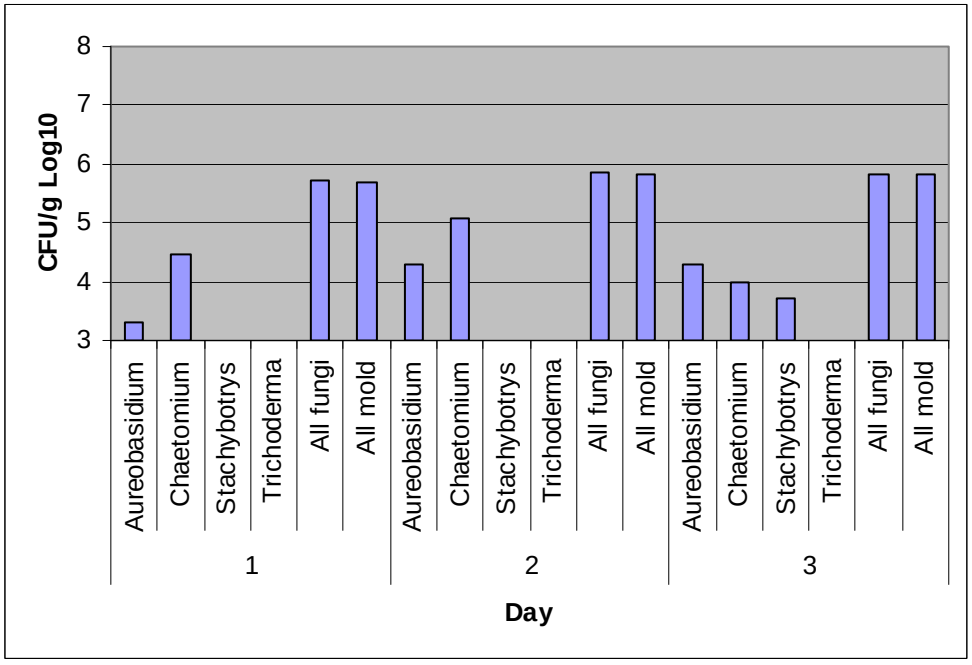


Figure N62. Building 5. Concentrations of *Aureobasidium*, *Chaetomium*, *Stachybotrys*, *Trichoderma* and the sum concentration of all culturable fungi (All fungi = mold + yeast+ non-sporulating mycelia) and culturable mold (All mold) in vacuum dust samples reported as the Log_{10} number of colony forming units per gram (CFU/g Log_{10}) for the three sampling days (Day 1, 2, and 3).

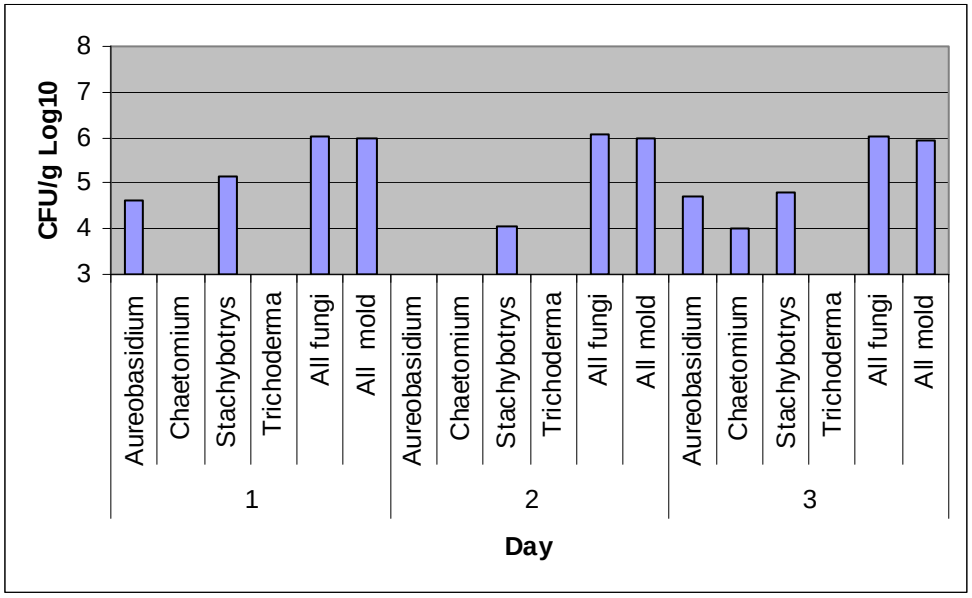


Figure N63. Building 6. Concentrations of *Aureobasidium*, *Chaetomium*, *Stachybotrys*, *Trichoderma* and the sum concentration of all culturable fungi (All fungi = mold + yeast+ non-sporulating mycelia) and culturable mold (All mold) in vacuum dust samples reported as the Log_{10} number of colony forming units per gram (CFU/g Log_{10}) for the three sampling days (Day 1, 2, and 3).

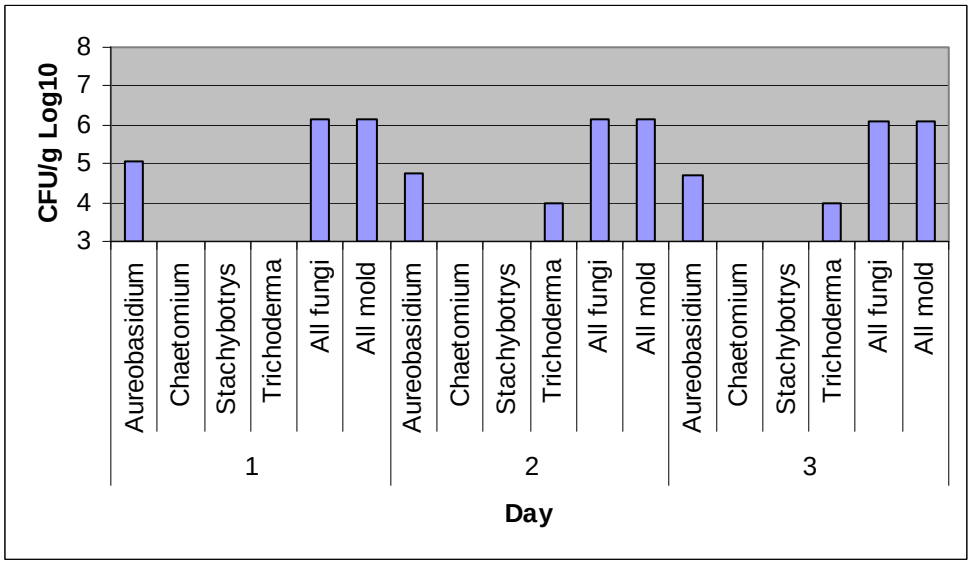


Figure N64. Building 7. Concentrations of *Aureobasidium*, *Chaetomium*, *Stachybotrys*, *Trichoderma* and the sum concentration of all culturable fungi (All fungi = mold + yeast+ non-sporulating mycelia) and culturable mold (All mold) in vacuum dust samples reported as the Log_{10} number of colony forming units per gram (CFU/g Log_{10}) for the three sampling days (Day 1, 2, and 3).

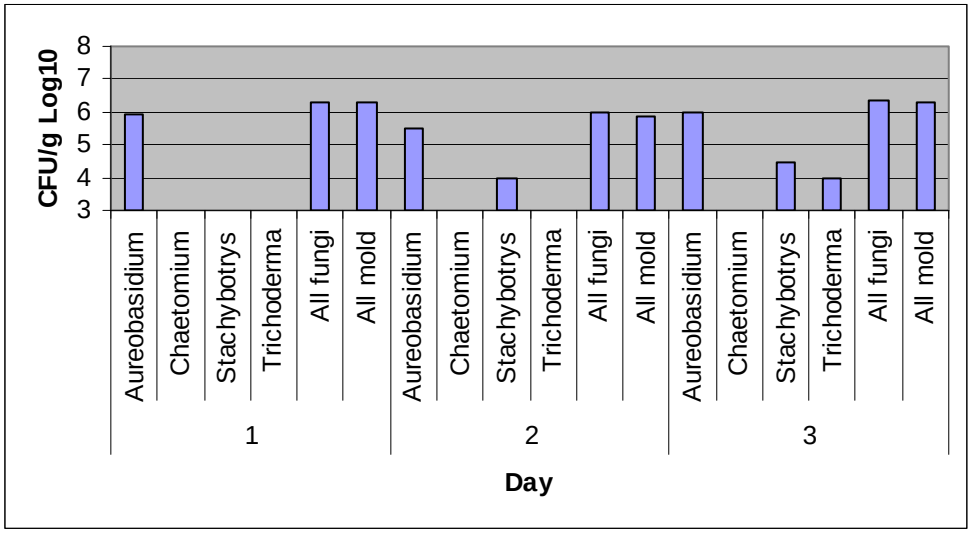


Figure N65. Building 8. Concentrations of *Aureobasidium*, *Chaetomium*, *Stachybotrys*, *Trichoderma* and the sum concentration of all culturable fungi (All fungi = mold + yeast+ non-sporulating mycelia) and culturable mold (All mold) in vacuum dust samples reported as the Log_{10} number of colony forming units per gram (CFU/g Log_{10}) for the three sampling days (Day 1, 2, and 3).

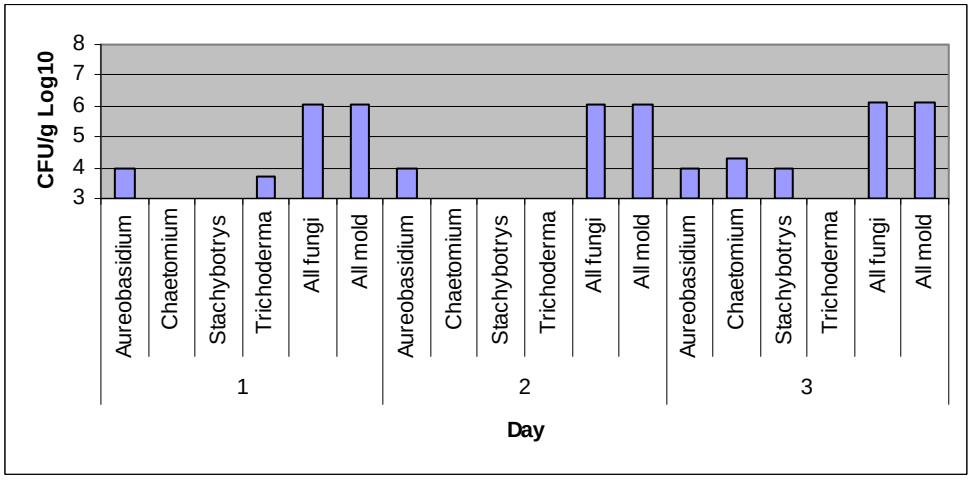


Figure N66. Building 9. Concentrations of *Aureobasidium*, *Chaetomium*, *Stachybotrys*, *Trichoderma* and the sum concentration of all culturable fungi (All fungi = mold + yeast+ non-sporulating mycelia) and culturable mold (All mold) in vacuum dust samples reported as the Log_{10} number of colony forming units per gram (CFU/g Log_{10}) for the three sampling days (Day 1, 2, and 3).

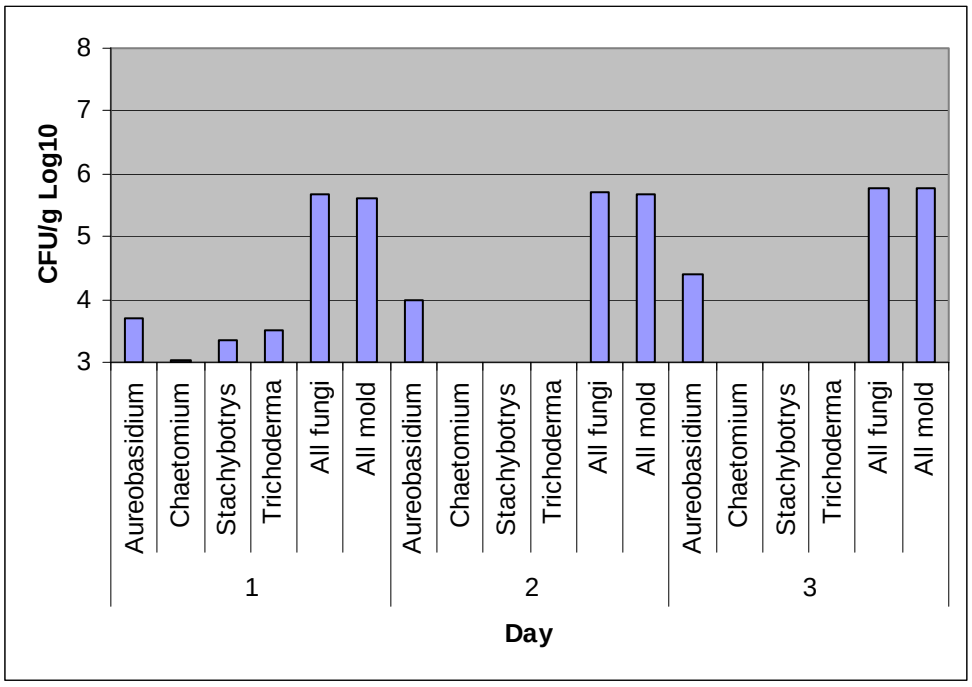


Figure N67. Building 10. Concentrations of *Aureobasidium*, *Chaetomium*, *Stachybotrys*, *Trichoderma* and the sum concentration of all culturable fungi (All fungi = mold + yeast+ non-sporulating mycelia) and culturable mold (All mold) in vacuum dust samples reported as the Log_{10} number of colony forming units per gram (CFU/g Log_{10}) for the three sampling days (Day 1, 2, and 3).

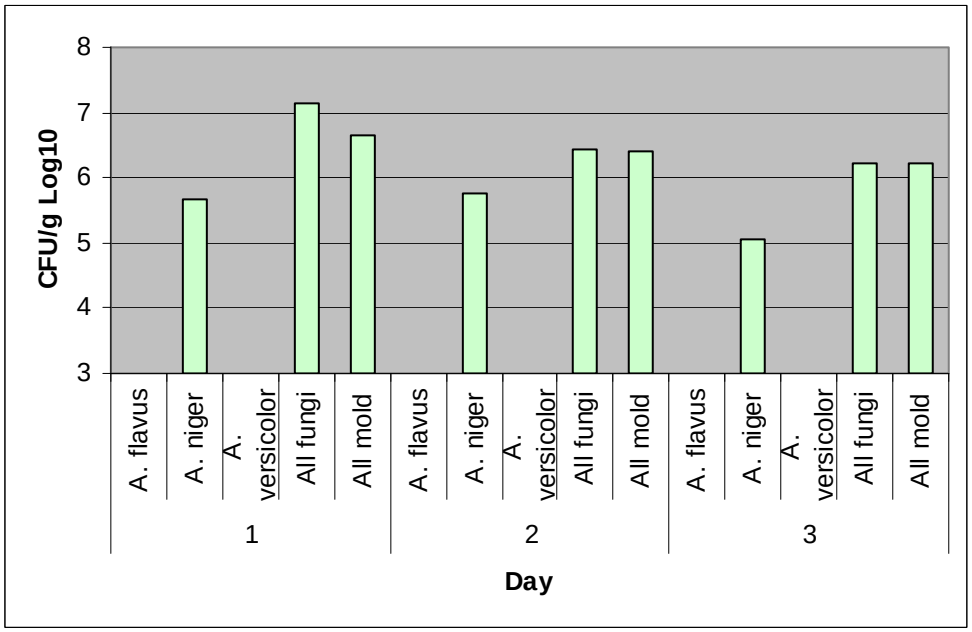


Figure N68. Building 1. Concentrations of water indicating species of *Aspergillus* (*A. flavus, A. niger*, and *A. versicolor*) and the sum concentration of all culturable mold (All mold) in vacuum dust samples reported as the Log_{10} number of colony forming units per gram (CFU/g Log_{10}) for the three sampling days (Day 1, 2, and 3).

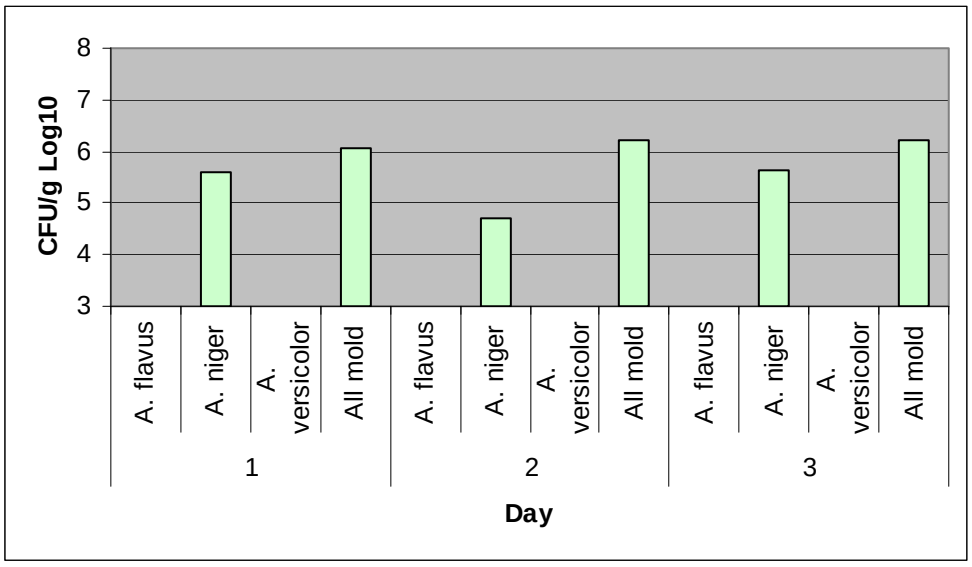


Figure N69. Building 2. Concentrations of water indicating species of *Aspergillus* (*A. flavus, A. niger*, and *A. versicolor*) and the sum concentration of all culturable mold (All mold) in vacuum dust samples reported as the Log_{10} number of colony forming units per gram (CFU/g Log_{10}) for the three sampling days (Day 1, 2, and 3).

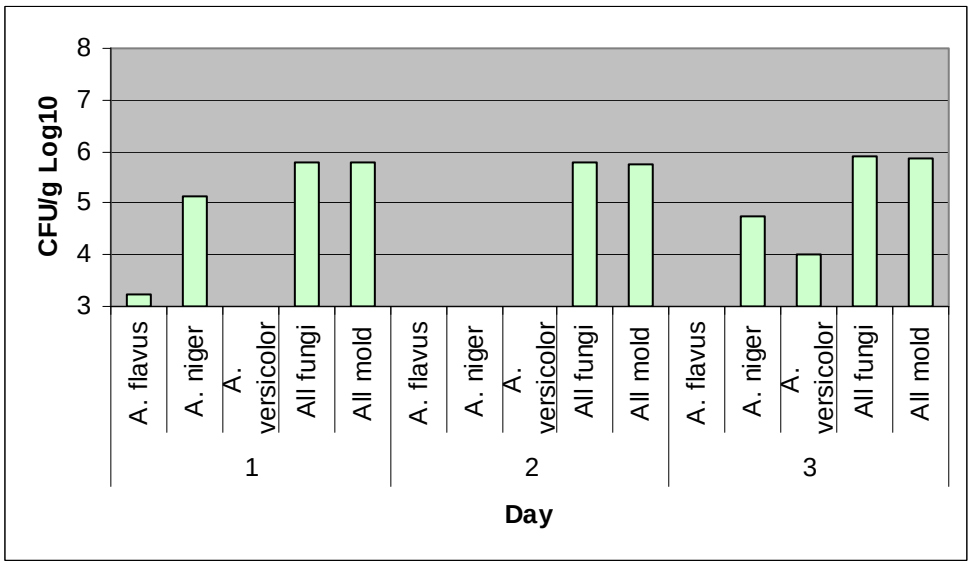


Figure N70. Building 3. Concentrations of water indicating species of *Aspergillus* (*A. flavus, A. niger*, and *A. versicolor*) and the sum concentration of all culturable mold (All mold) in vacuum dust samples reported as the Log_{10} number of colony forming units per gram (CFU/g Log_{10}) for the three sampling days (Day 1, 2, and 3).

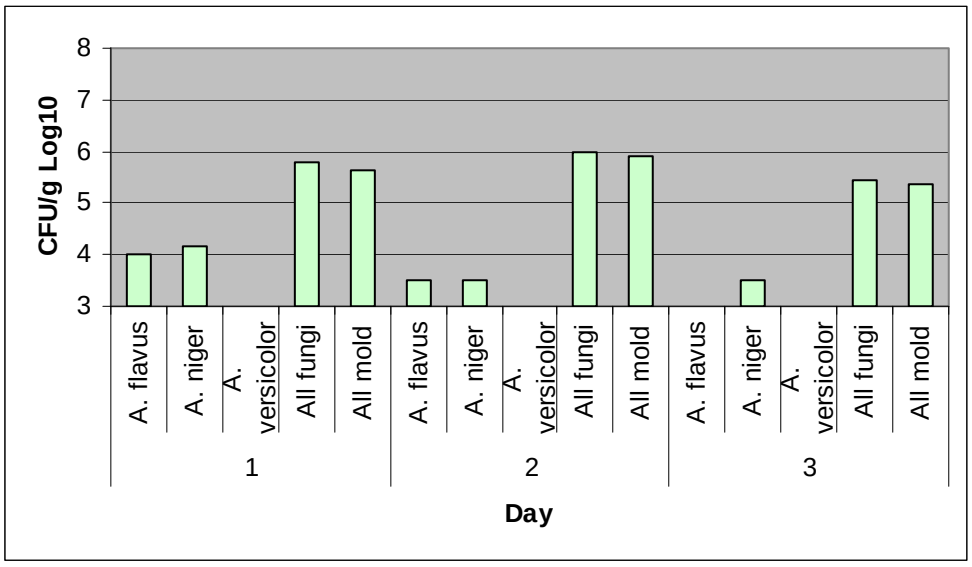


Figure N71. Building 4. Concentrations of water indicating species of *Aspergillus* (*A. flavus, A. niger*, and *A. versicolor*) and the sum concentration of all culturable mold (All mold) in vacuum dust samples reported as the Log_{10} number of colony forming units per gram (CFU/g Log_{10}) for the three sampling days (Day 1, 2, and 3).

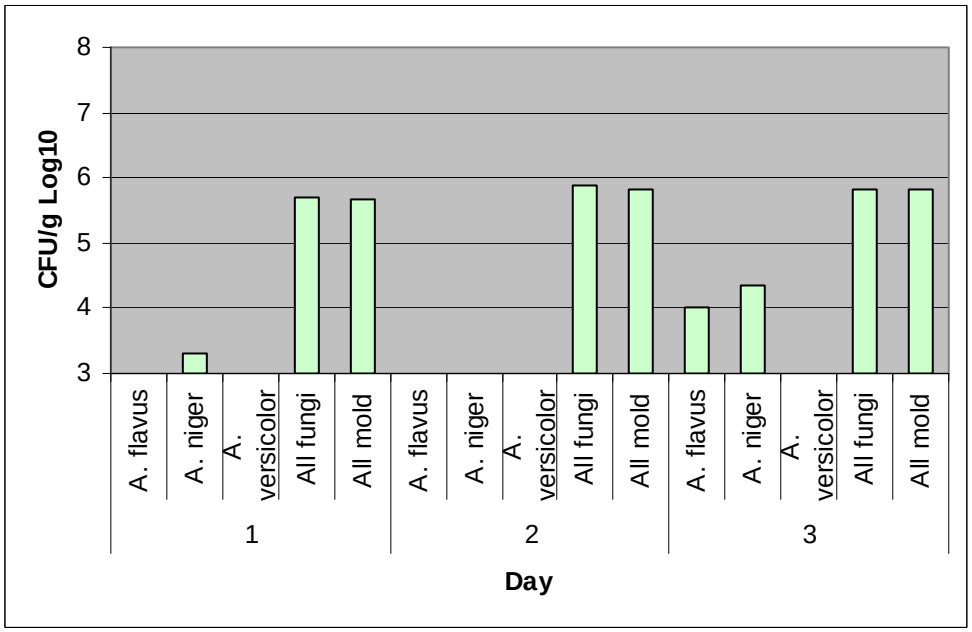


Figure N72. Building 5. Concentrations of water indicating species of *Aspergillus* (*A. flavus, A. niger*, and *A. versicolor*) and the sum concentration of all culturable mold (All mold) in vacuum dust samples reported as the Log_{10} number of colony forming units per gram (CFU/g Log_{10}) for the three sampling days (Day 1, 2, and 3).

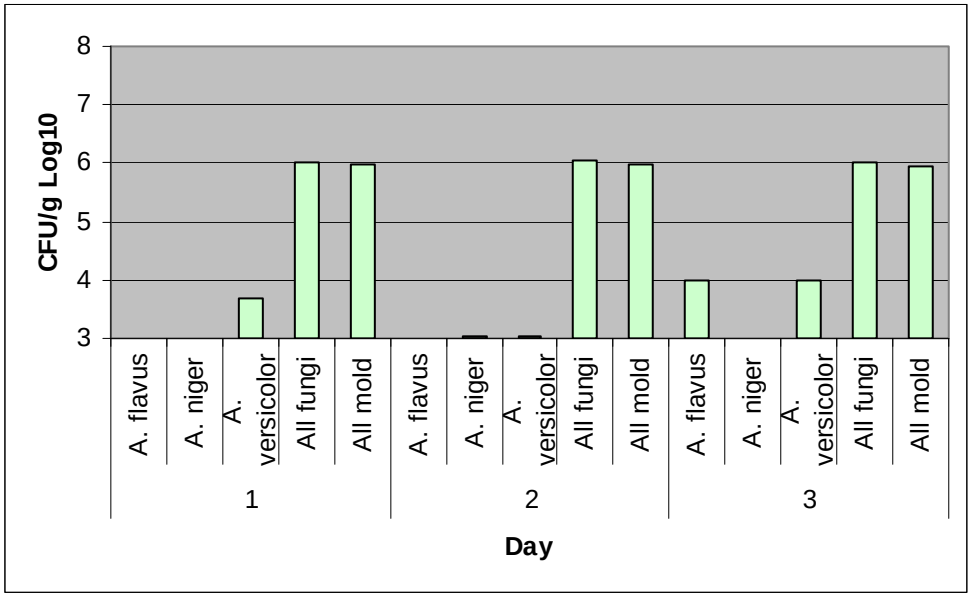


Figure N73. Building 6. Concentrations of water indicating species of *Aspergillus* (*A. flavus, A. niger*, and *A. versicolor*) and the sum concentration of all culturable mold (All mold) in vacuum dust samples reported as the Log_{10} number of colony forming units per gram (CFU/g Log_{10}) for the three sampling days (Day 1, 2, and 3).

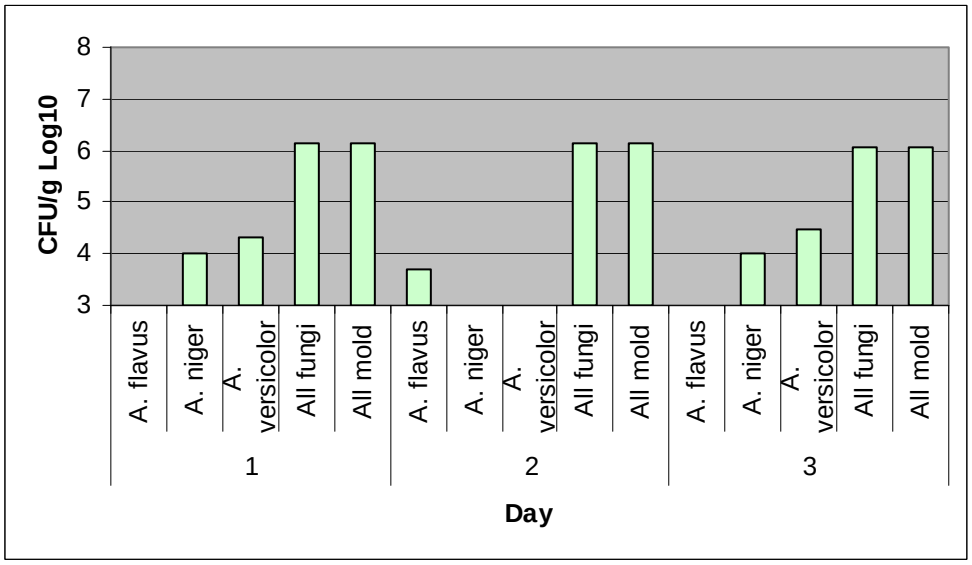


Figure N74. Building 7. Concentrations of water indicating species of *Aspergillus* (*A. flavus, A. niger*, and *A. versicolor*) and the sum concentration of all culturable mold (All mold) in vacuum dust samples reported as the Log_{10} number of colony forming units per gram (CFU/g Log_{10}) for the three sampling days (Day 1, 2, and 3).

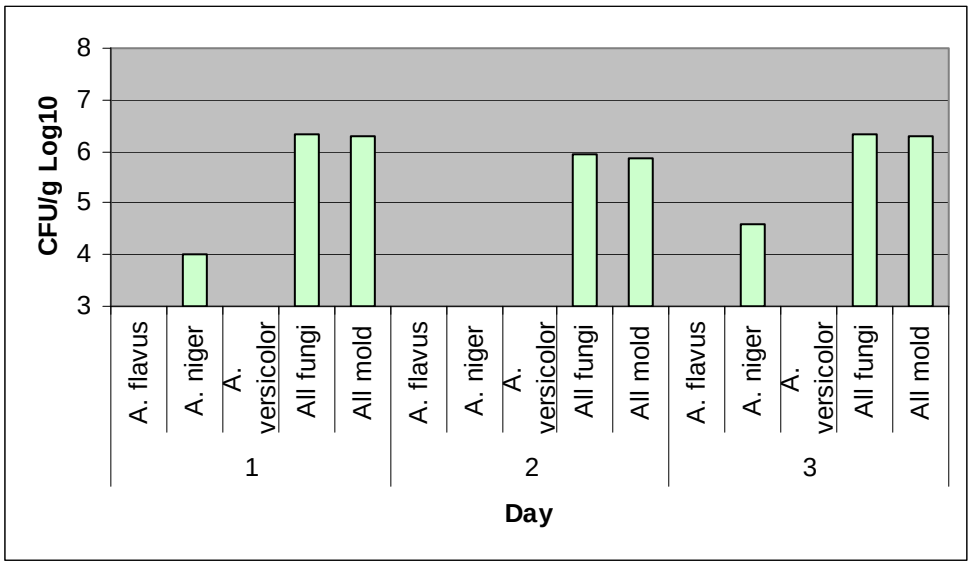


Figure N75. Building 8. Concentrations of water indicating species of *Aspergillus* (*A. flavus, A. niger*, and *A. versicolor*) and the sum concentration of all culturable mold (All mold) in vacuum dust samples reported as the Log_{10} number of colony forming units per gram (CFU/g Log_{10}) for the three sampling days (Day 1, 2, and 3).

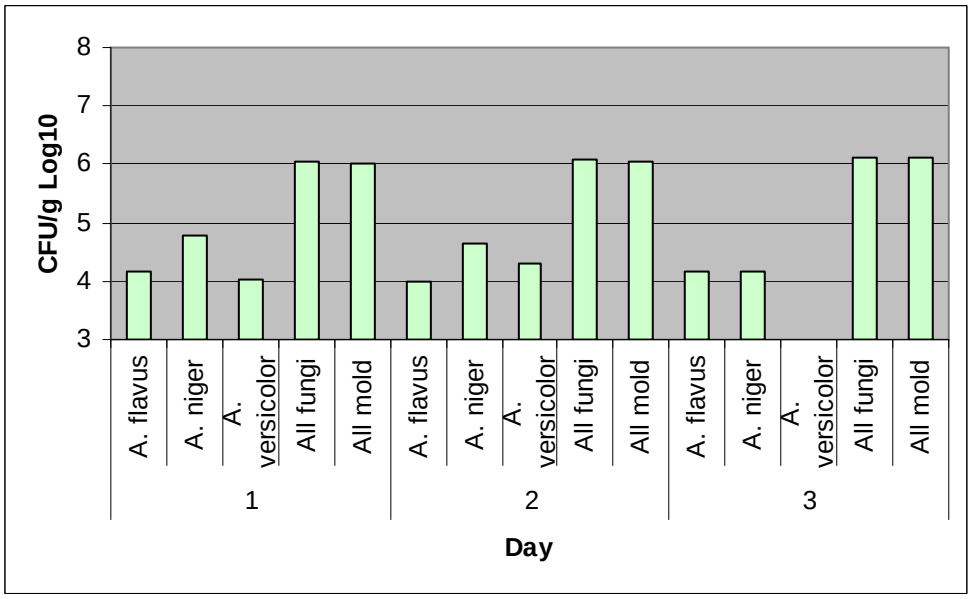


Figure N76. Building 9. Concentrations of water indicating species of *Aspergillus* (*A. flavus, A. niger*, and *A. versicolor*) and the sum concentration of all culturable mold (All mold) in vacuum dust samples reported as the Log_{10} number of colony forming units per gram (CFU/g Log_{10}) for the three sampling days (Day 1, 2, and 3).

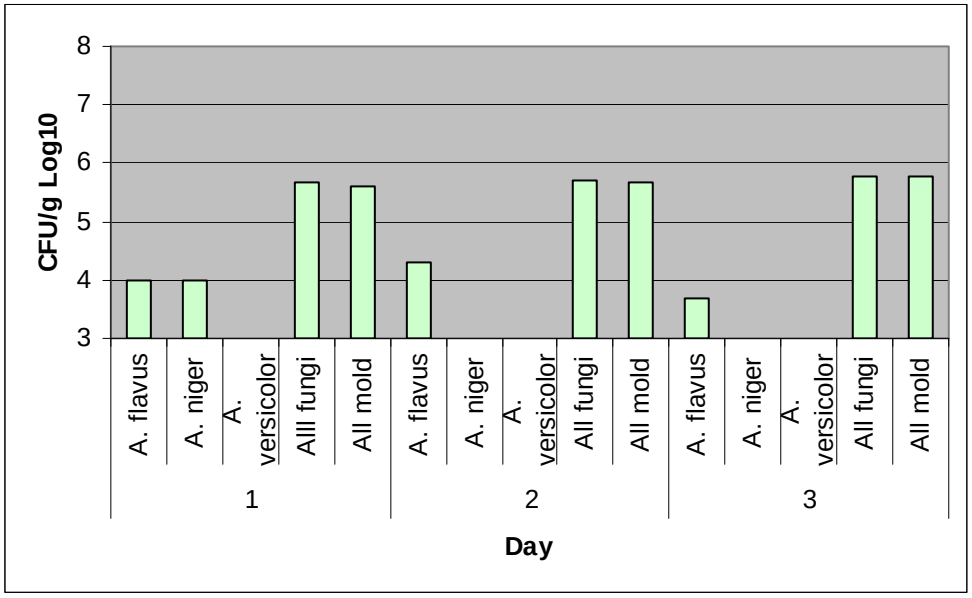


Figure N77. Building 10. Concentrations of water indicating species of *Aspergillus* (*A. flavus, A. niger*, and *A. versicolor*) and the sum concentration of all culturable mold (All mold) in vacuum dust samples reported as the Log_{10} number of colony forming units per gram (CFU/g Log_{10}) for the three sampling days (Day 1, 2, and 3).

APPENDIX O: STATISTICAL RESULTS FOR MOLD

O1. Determination of zone effect on the presence of a predominant taxon in air samples (Bldg ID = building designation; yellow highlight = significant [$p<0.05$]; green highlight = moderately significant [$0.05<p<0.075$]).

Table O1. Chi square values for presence of a predominant taxon in airborne culturable fungal samples.

Building ID	Chi Square	Prob. Chi Square
1	0	1
3	0	1
4	0	
5	5.004024	0.08192000
6	3.819085	0.14814815
7	0	
8	6.278978	0.09879871

Table O2. Chi square values for presence of a predominant taxon in airborne non-culturable fungal samples.

Building ID	Chi Square	Prob Chi Square
1	3.819085	0.14814815
3	1.726092	0.1889107
5	7.050924	0.21688052
6	0	1
7	7.63817	0.05411256
9	0	

O2. VARIANCE COMPONENT ANALYSIS OF AIRBORNE FUNGI

Table O3. Variance component analysis of airborne culturable fungi.

CovParm	Estimate	Variable	Sum	Percentage
Bldg ID	0	*Cladosporium*	0.025899239	0%
Zone(Bldg ID)	0.000115588	*Cladosporium*		0%
Day (Bldg ID)	0.006160102	*Cladosporium*		24%
Residual	0.019623549	*Cladosporium*		76%
Bldg ID	0	Predominant taxon	0.261257225	<1%
Zone(Bldg ID)	0.1602806	Predominant taxon		61%
Day(Bldg ID)	0.071218099	Predominant taxon		27%
Residual	0.029758526	Predominant taxon		11%

Table O4. Variance component analysis of airborne non-culturable fungal spores.

CovParm	Estimate	Variable	Sum	Percentage
Bldg ID	0.000833100	*Cladosporium*	0.062929393	1%
Zone(Bldg ID)	0.012780036	*Cladosporium*		20%
Day (Bldg ID)	0.004459805	*Cladosporium*		7%
Residual	0.044856452	*Cladosporium*		71%
Bldg ID	0.072852852	Predominant taxon	0.258763129	28%
Zone(Bldg ID)	0.081739682	Predominant taxon		32%
Day(Bldg IDI)	0.010588304	Predominant taxon		4%
Residual	0.093582291	Predominant taxon		36%

O3. Statistical Results In Comparison Of Indoor And Outdoor Airborne Fungi

(Bldg ID = building designation; Type = statistical analysis performed; Corr = correlation, yellow highlight = significant [p<0.05]; green highlight = moderately significant [0.05<p<0.075]).

Table O5. Results of culturable fungi.

Bldg ID	Type	Corr	p value
1	Pearson	0.122503	0.628206
1	Spearman	0.305197	0.218125
2	Pearson	0.827356	0.000000
2	Spearman	0.688279	0.000201
3	Pearson	-0.17249	0.480107
3	Spearman	-0.15464	0.527316
4	Pearson	0.171851	0.495328
4	Spearman	-0.06850	0.787105
5	Pearson	0.355399	0.135377
5	Spearman	0.312926	0.192076
6	Pearson	0.704818	0.000520
6	Spearman	0.409376	0.073069
7	Pearson	0.076269	0.763575
7	Spearman	-0.09681	0.702358
8	Pearson	0.488563	0.028832
8	Spearman	0.320378	0.168469
9	Pearson	0.643377	0.003969
9	Spearman	0.608159	0.007411
10	Pearson	0.402696	0.097548
10	Spearman	0.241382	0.334571

Table O6. Results of non-culturable fungi

Bldg ID	Type	Corr	p value
1	Pears	0.569137	0.013697
1	Spear	0.266749	0.284613
2	Pears	0.293065	0.197299
2	Spear	0.02286	0.921651
3	Pears	-0.0764	0.755905
3	Spear	-0.01835	0.940572
4	Pears	0.576993	0.012175
4	Spear	0.660876	0.002827
5	Pears	0.084165	0.709606
5	Spear	-0.01177	0.958557
6	Pears	0.697992	0.000890
6	Spear	0.531647	0.019145
7	Pears	-0.04353	0.851395
7	Spear	0.090701	0.695797
8	Pears	0.547723	0.008322
8	Spear	0.569541	0.005661
9	Pears	0.292747	0.238436
9	Spear	0.212076	0.398201
10	Pears	-0.04197	0.864536
10	Spear	0.22295	0.358900

04. RATIOS AMONG THE SIX INDOOR LOCATIONS (ZONES)

Table 07. Across sampling days for airborne culturable fungi.

Bldg ID	Mean	Std Dev	Minimum	Maximum
1	1	0	1	1
2	1.1080	0.4583	1	2.944
3	1	0	1	1
4	1	0	1	1
5	1	0	1	1
6	1	0	1	1
7	1	0	1	1
8	1	0	1	1
9	1	0	1	1
10	1	0	1	1

Table 08. Across sampling days for airborne non-culturable fungi.

Bldg ID	Mean	Std	Minimum	Maximum
1	1	0	1	1
2	1.0588	0.2425	1	2
3	1	0	1	1
4	1	0	1	1
5	1.0625	0.2500	1	2
6	1	0	1	1
7	1.0625	0.2500	1	2
8	1.088	0.2642	1	2
9	1	0	1	1
10	1	0	1	1

Table O9. Within the same sampling day for airborne culturable fungi.

Bldg ID	Mean	Std Dev	Minimum	Maximum
1	1	0	1	1
2	1.11	0.4583	1	2.9
3	1	0	1	1
4	1	0	1	1
5	1	0	1	1
6	1	0	1	1
7	1	0	1	1
8	1	0	1	1
9	1	0	1	1
10	1	0	1	1

Table O10. Within the same sampling day for airborne non-culturable fungi.

Bldg ID	Mean	Std Dev	Minimum	Maximum
1	1	0	1	1
2	1.06	0.2425	1	2
3	1	0	1	1
4	1	0	1	1
5	1.06	0.2500	1	2
6	1	0	1	1
7	1.06	0.2500	1	2
8	1.09	0.2643	1	2
9	1	0	1	1
10	1	0	1	1

05. Statistical Results Indoor Vs. Outdoor

Table O11. Statistical results in comparison of culturable fungi in indoor and outdoor air samples (Type = statistical analysis performed; Corr = correlation, yellow highlight = significant [p<0.05]; green highlight = moderately significant [0.05<p<0.075]).

Bldg ID	Type	Corr	p value
	Pearson	0.369848	1.29E-07
	Spearman	0.492866	3.81E-13
1	Pearson	0.122503	0.628206
1	Spearman	0.305197	0.218125
2	Pearson	0.827356	0.000001
2	Spearman	0.688279	0.000201
3	Pearson	-0.17249	0.480107
3	Spearman	-0.15464	0.527316
4	Pearson	0.171851	0.495328
4	Spearman	-0.0685	0.787105
5	Pearson	0.355399	0.135377
5	Spearman	0.312926	0.192076
6	Pearson	0.704818	0.000520
6	Spearman	0.409376	0.073069
7	Pearson	0.076269	0.763575
7	Spearman	-0.09681	0.702358
8	Pearson	0.488563	0.028832
8	Spearman	0.320378	0.168469
9	Pearson	0.643377	0.003969
9	Spearman	0.608159	0.007411
10	Pearson	0.402696	0.097548
10	Spearman	0.241382	0.334571

Table O12. Statistical results in comparison of non-culturable fungi in indoor and outdoor air samples (Type = statistical analysis performed; Corr = correlation, yellow highlight = significant [p<0.05]; green highlight = moderately significant [0.05<p<0.075]).

Bldg ID	Type	Corr	P value
	Pearson	0.290946	3.36E-05
	Spearman	0.452085	2.58E-11
1	Pearson	0.569137	0.013697
1	Spearman	0.266749	0.284613
2	Pearson	0.293065	0.197299
2	Spearman	0.022860	0.921651
3	Pearson	-0.07640	0.755905
3	Spearman	-0.01835	0.940572
4	Pearson	0.576993	0.012175
4	Spearman	0.660876	0.002827
5	Pearson	0.084165	0.709606
5	Spearman	-0.01177	0.958557
6	Pearson	0.697992	0.000890
6	Spearman	0.531647	0.019145
7	Pearson	-0.04353	0.851395
7	Spearman	0.090701	0.695797
8	Pearson	0.547723	0.008322
8	Spearman	0.569541	0.005661
9	Pearson	0.292747	0.238436
9	Spearman	0.212076	0.398201
10	Pearson	-0.04197	0.864536
10	Spearman	0.222950	0.358900

06. WATER INDICATING FUNGI

Table O13. Frequency of water indicator fungi isolated from indoor culturable air samples (Variable = the taxon and target percentage; n = the number of samples analyzed; % of samples = percentage of samples within the variable criteria).

Variable	n	% of samples
Stachybotrys <1%	192	100
Trichoderma <1%	192	100
Chaetomium <1%	192	100
Aureobasidium <1%	192	100
Aspergillus versicolor <15%	188	98
Aspergilus flavus <15%	191	99
Aspergillus niger <15%	185	96
Penicillium <30%	170	89

O7. ERROR PLOTS DEMONSTRATING VARIABILITY AMONG DAYS AND LOCATIONS

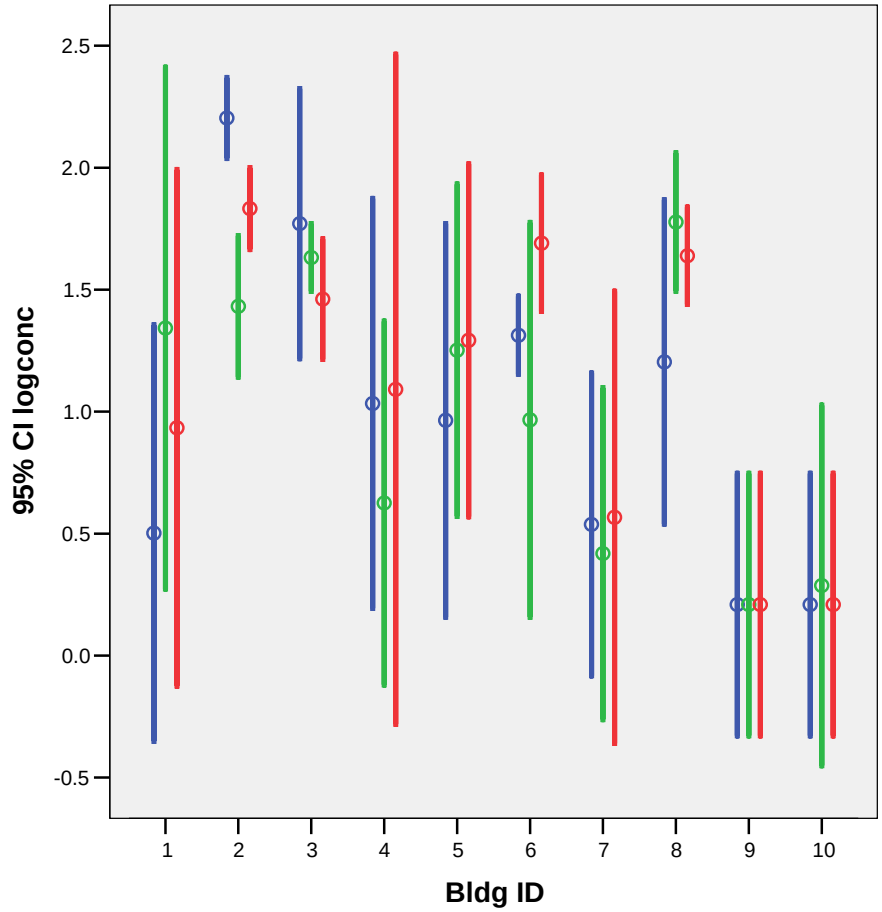


Figure O1. Error bar plot at the 95% confidence for airborne culturable data (Andersen samples). For each of the 10 buildings (Bldg ID), overlapping lines indicate no significant difference between the days (day 1 [blue], 2[green], and 3 [red]).

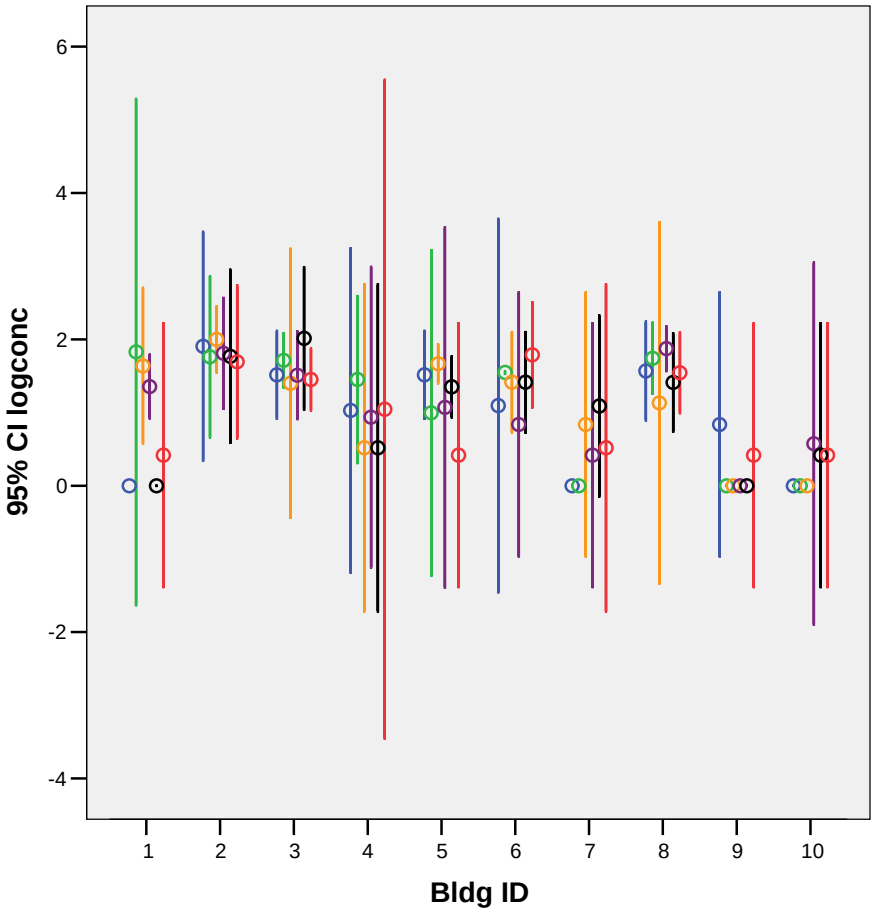


Figure O2. Error bar plot at the 95% confidence for airborne culturable data (Andersen samples). For each of the 10 buildings 9Bldg ID), overlapping lines indicate no significant difference between locations (location 1 [blue], 2 [green], 3 [orange], 4 [purple], 5 [black], 6 [red]).

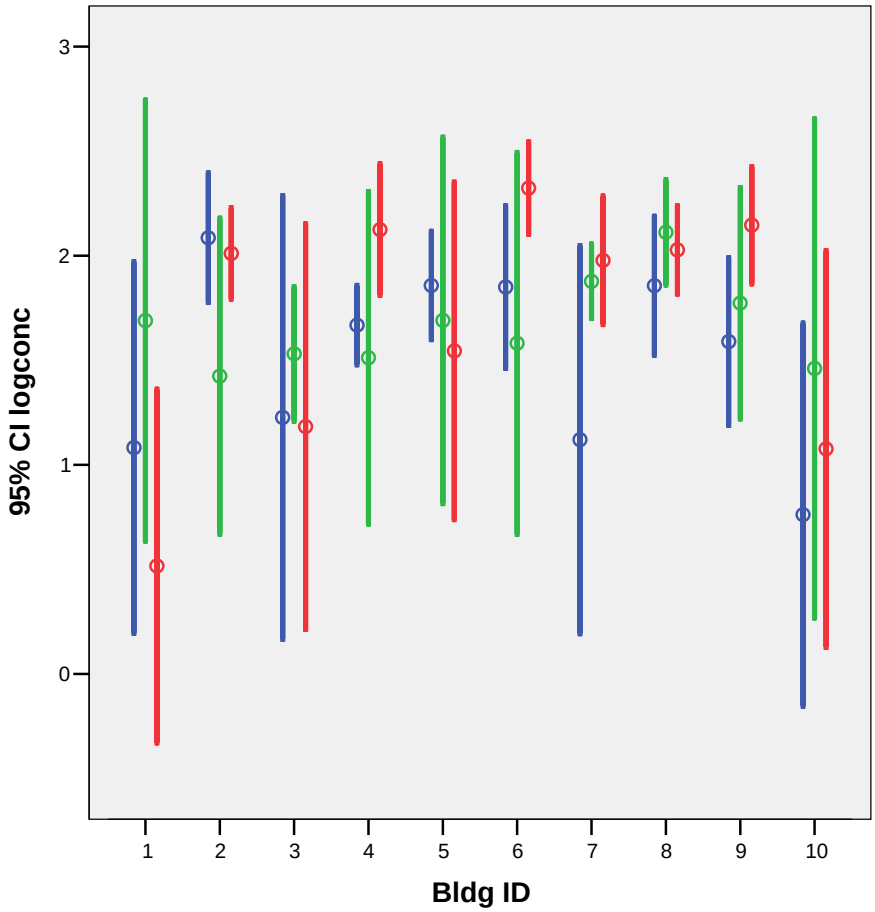


Figure O3. Error bar plot at the 95% confidence for airborne non-culturable data (Burkard samples). For each of the 10 buildings (Bldg ID), overlapping lines indicate no significant difference between the days (day 1 [blue], 2[green], and 3 [red])

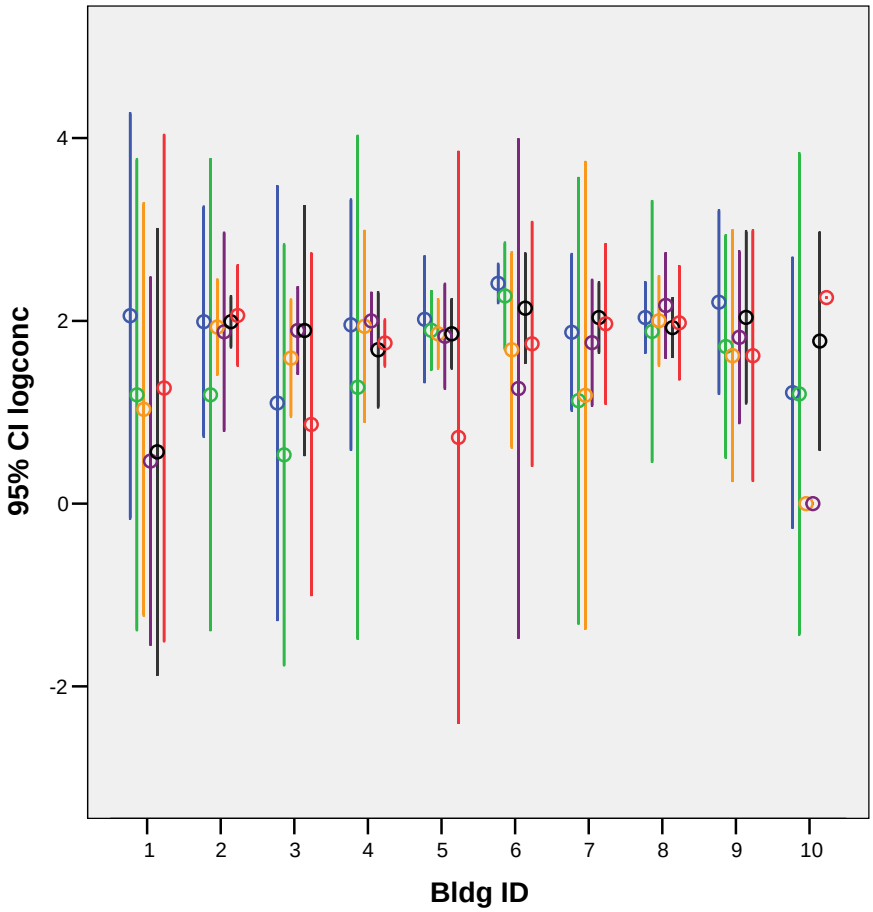


Figure O4. Error bar plot at the 95% confidence for airborne non-culturable data (Burkard samples). For each of the 10 buildings 9Bldg ID), overlapping lines indicate no significant difference between locations (location 1 [blue], 2 [green], 3 [orange], 4 [purple], 5 [black], 6 [red]).

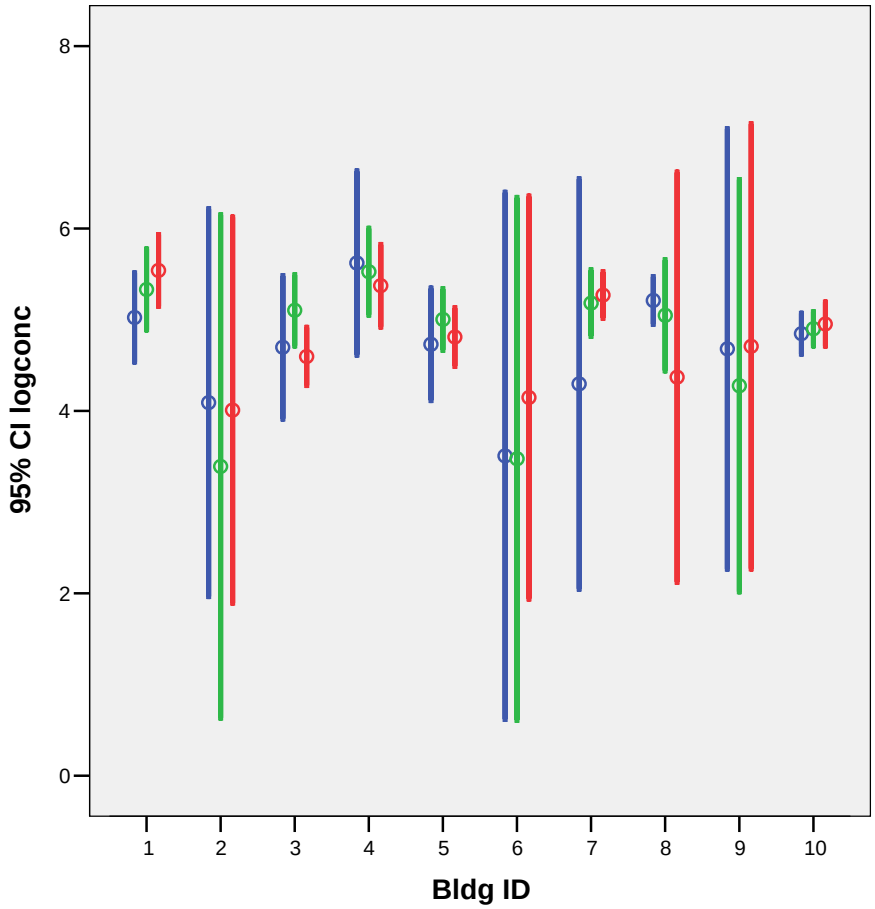


Figure O5. Error bar plot at the 95% confidence for surface-associated culturable fungi (vacuum dust samples). For each of the 10 buildings (Bldg ID), overlapping lines indicate no significant difference between the days (day 1 [blue], 2[green], and 3 [red]).

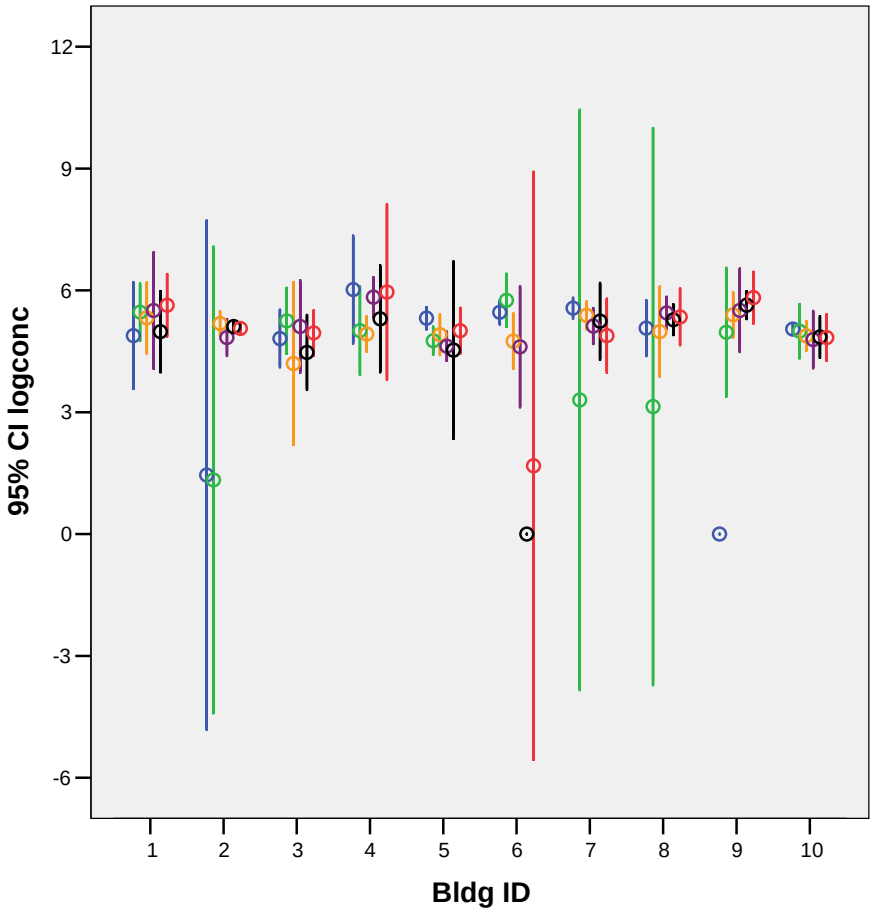


Figure O6. Error bar plot at the 95% confidence for surface-associated culturable fungi (vacuum dust samples). For each of the 10 buildings 9Bldg ID), overlapping lines indicate no significant difference between locations (location 1 [blue], 2 [green], 3 [orange], 4 [purple], 5 [black], 6 [red]).

APPENDIX P – SOUND RESULTS

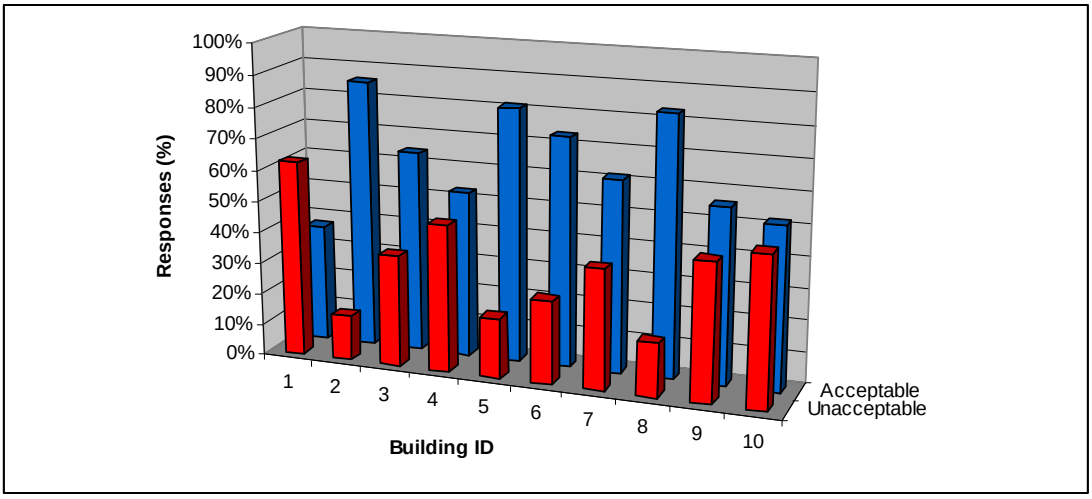


Figure P1. Summary of occupants' responses on the perception questionnaire concerning the acceptability of the sound/noise in their work area.

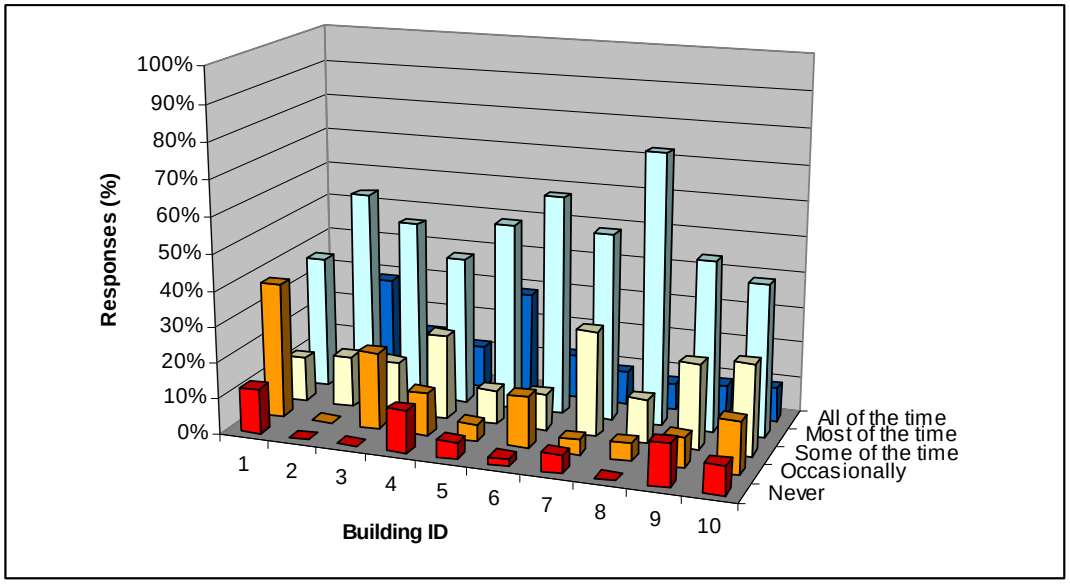


Figure P2. Specific responses on the occupant perception questionnaire when asked how often the sound/noise in their work area was acceptable.

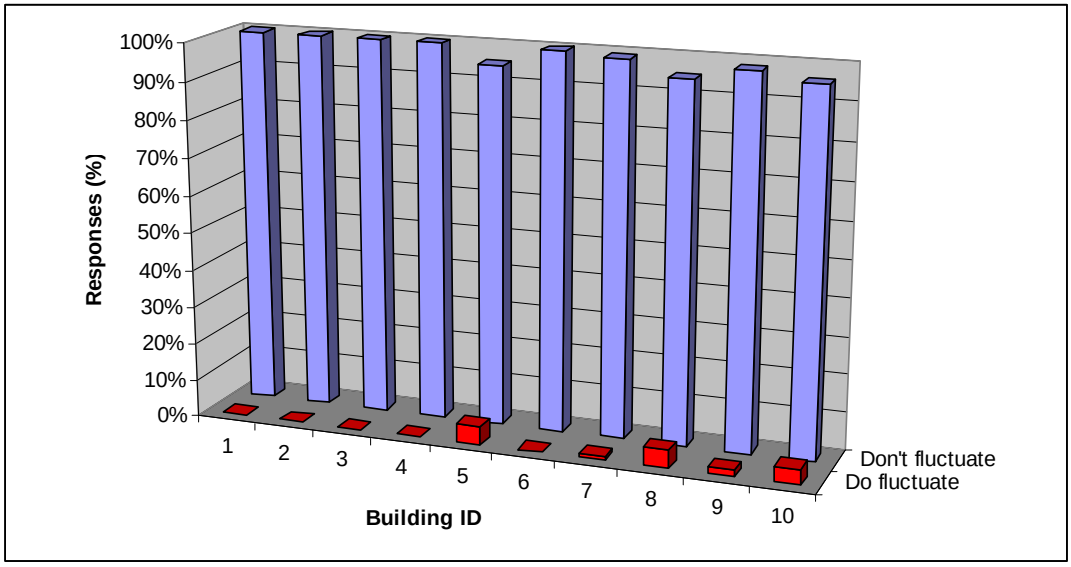


Figure P3. Summary of occupants' responses on the perception questionnaire concerning sound/noise fluctuation in their work area.

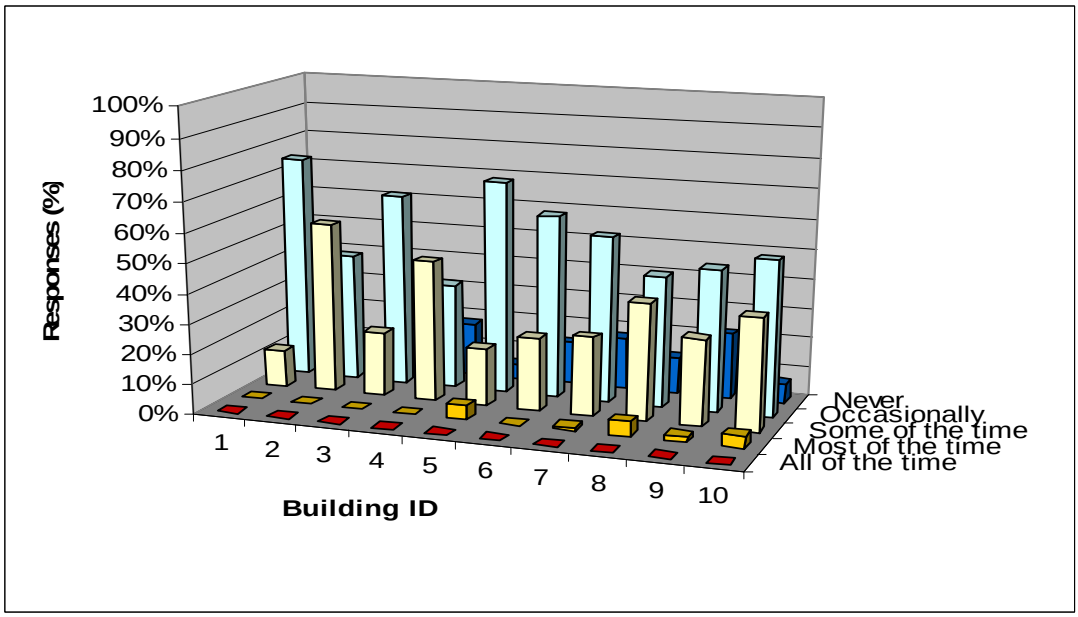


Figure P4. Specific responses on the occupant perception questionnaire when asked how often sound fluctuates in their work area.

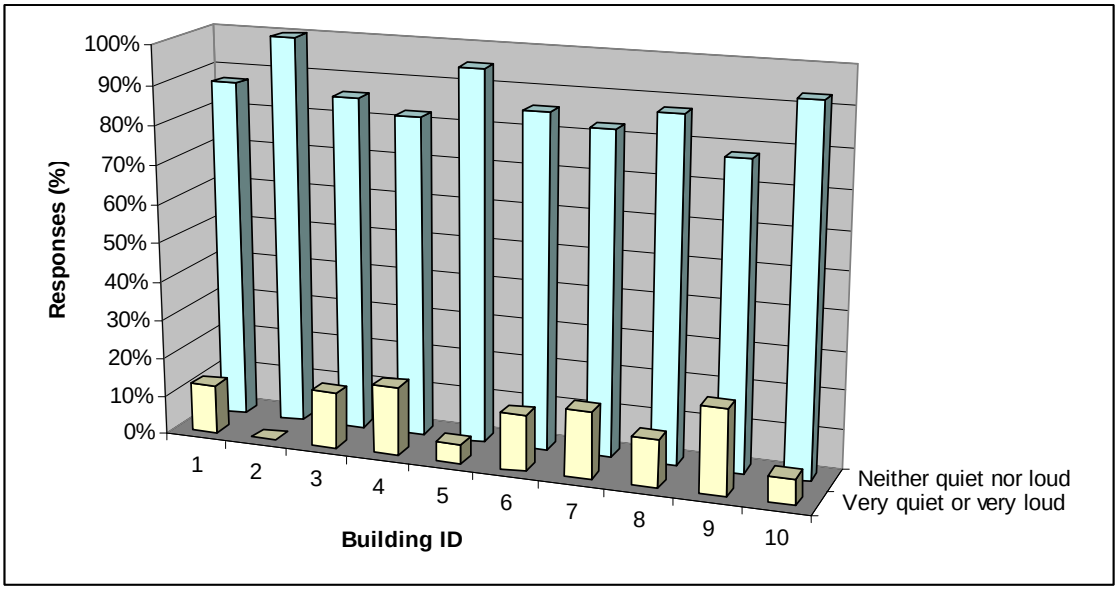


Figure P5. Summary of occupants' responses on the perception questionnaire when asked how they liked the sound in their workplace.

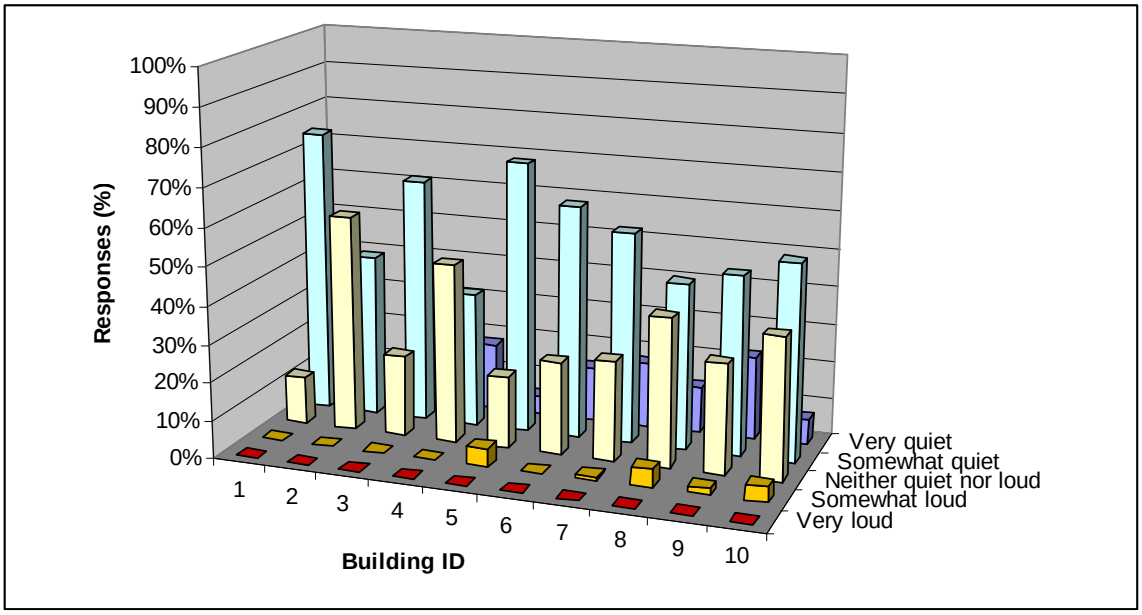


Figure P6. Specific responses on the occupant perception questionnaire when asked what volume of sound/noise in their work area was most comfortable.

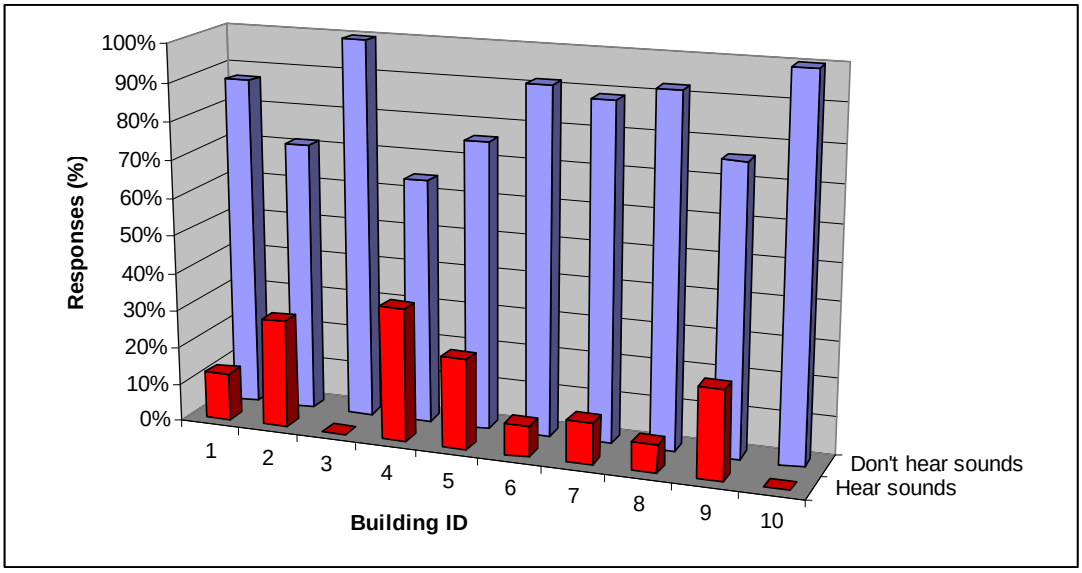


Figure P7. Summary of occupants' responses on the perception questionnaire concerning the hearing of sound/noise from outside of their building.

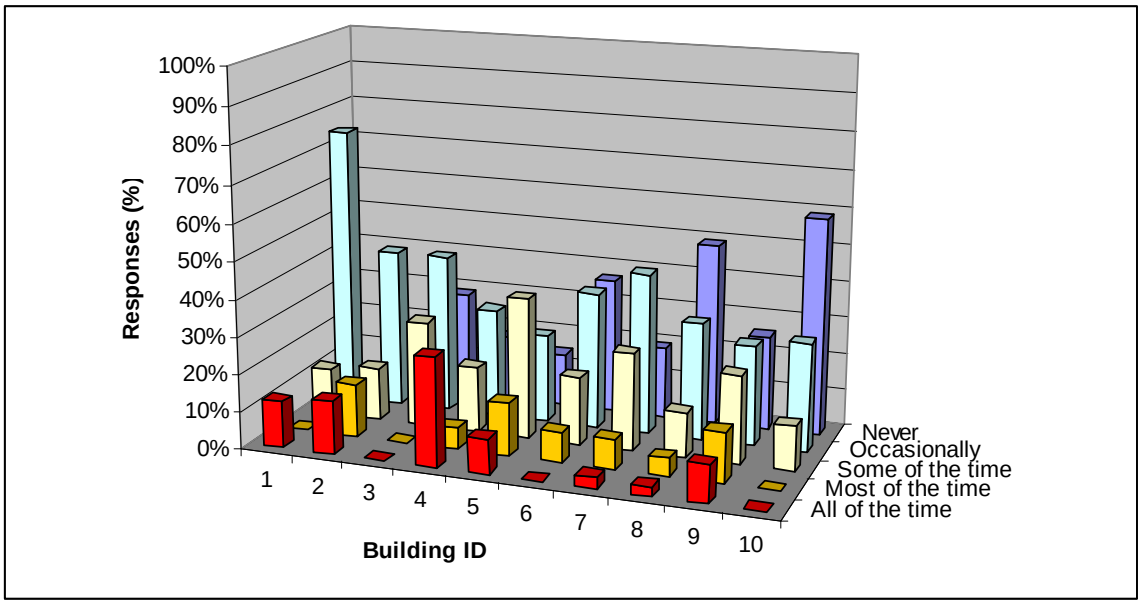


Figure P8. Specific responses on the occupant perception questionnaire when asked how often they could hear sound/noise from outside of their building.

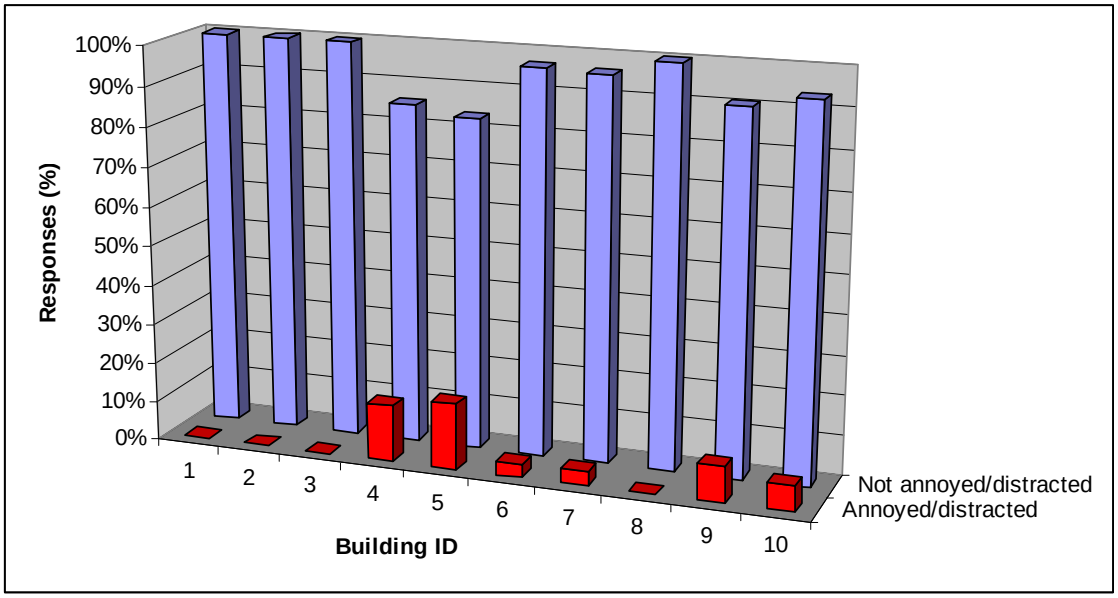


Figure P9. Summary of occupants' responses on the perception questionnaire concerning annoyance or distraction by noise from outside of their building.

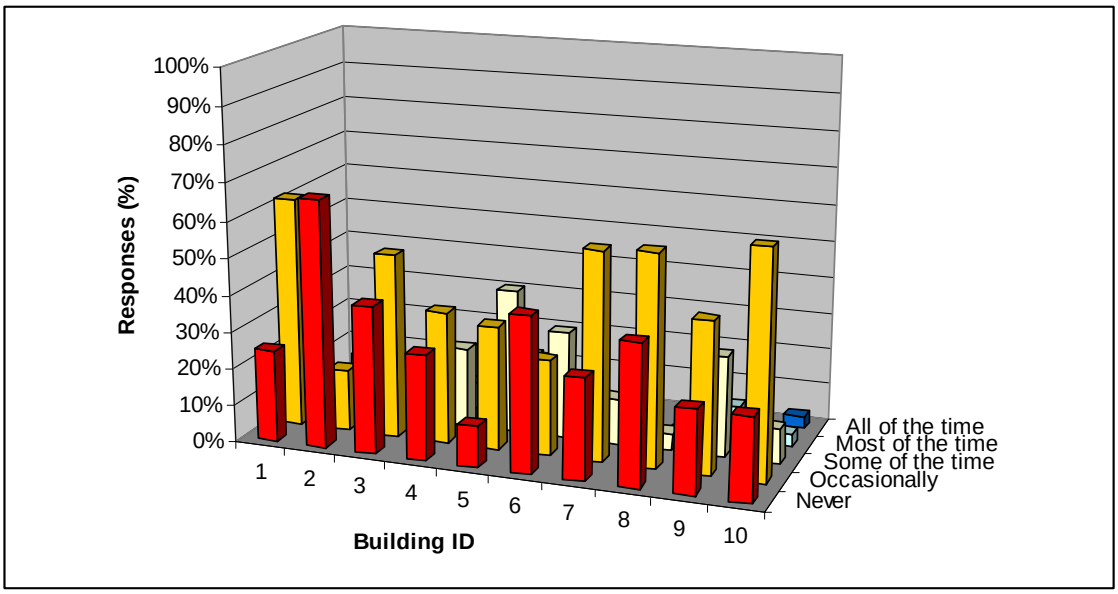


Figure P10. Specific responses on the occupant perception questionnaire when asked how often they were annoyed or distracted by noise from outside their building.

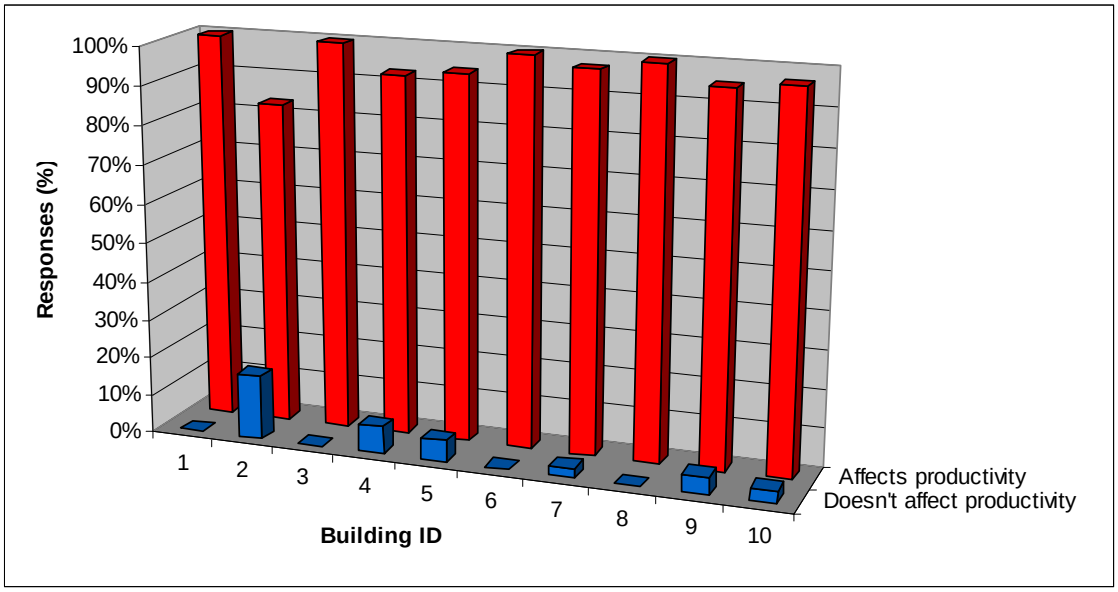


Figure P11. Summary of occupants' responses on the perception questionnaireconcerning the noise from outside the building affecting their productivity.

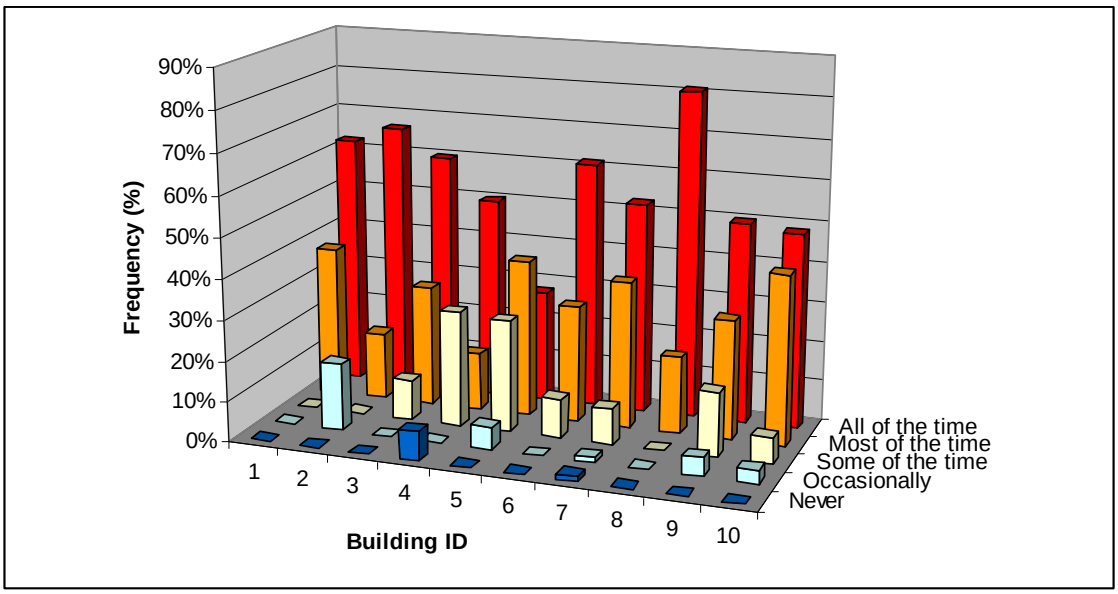


Figure P12. Specific responses on the perception questionnaire
when asked how often noise from outside the building affected their productivity.

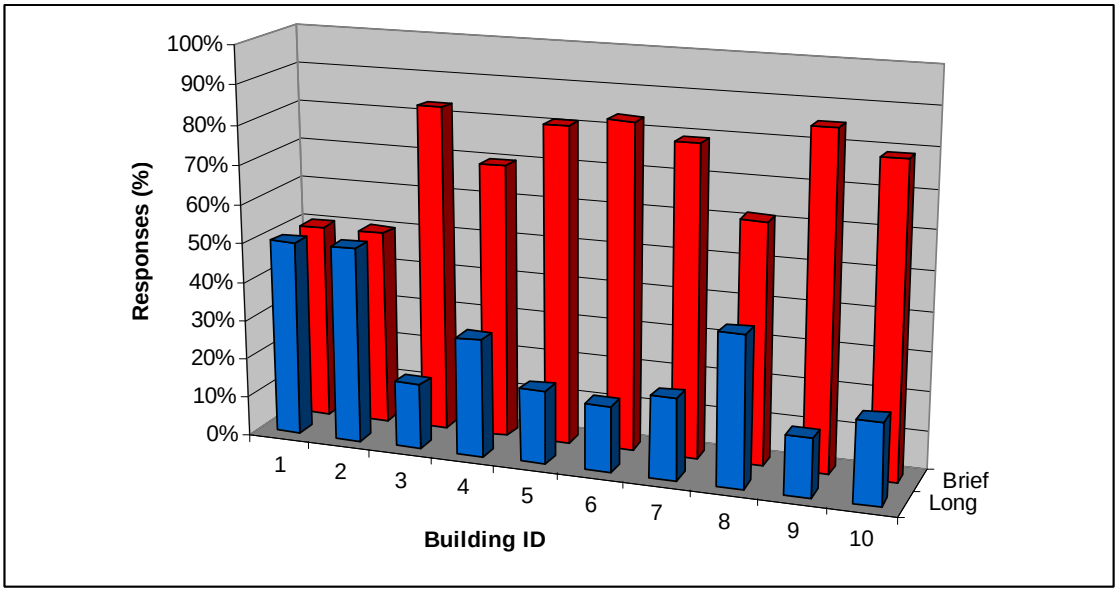


Figure P13. Summary of occupants' responses on the perception questionnaire concerning the time period (brief or long period) between when they hear the sound/noise from outside of the building and they are distracted.

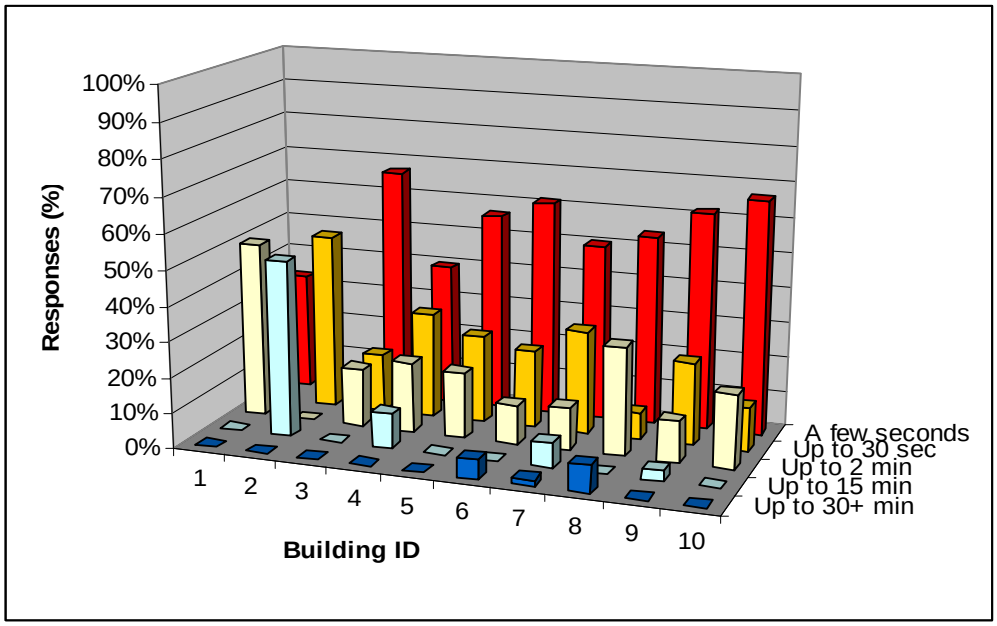


Figure P14. Specific responses on the occupant perception questionnaire when asked how quickly the distraction starts after hearing sound/noise from outside of the building.

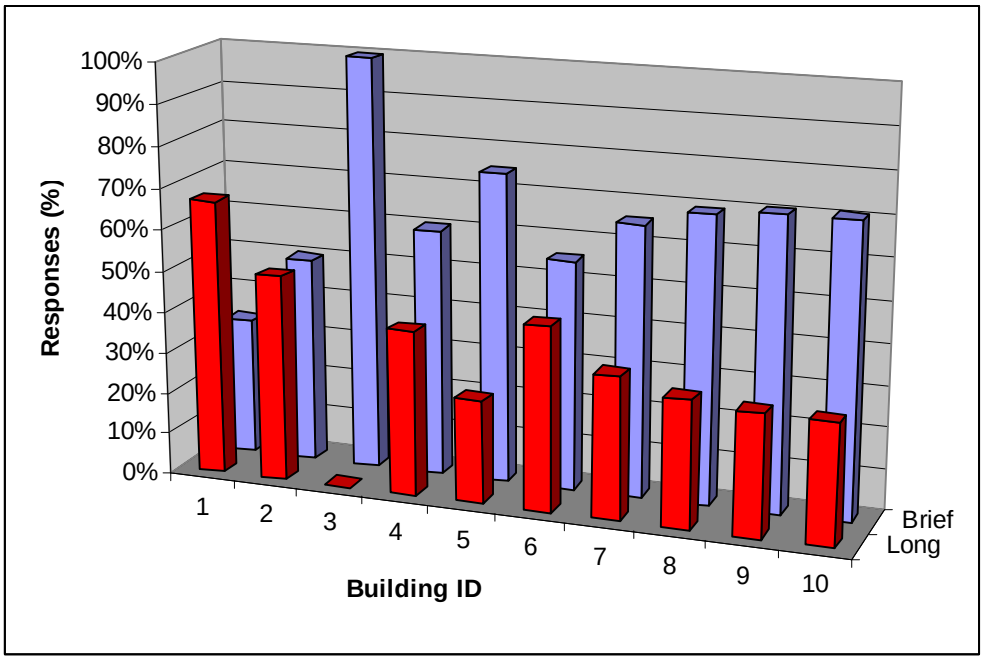


Figure P15. Summary of occupants' responses on the perception questionnaire concerning the length (brief or long period) of distraction from sound/noise outside of the building.

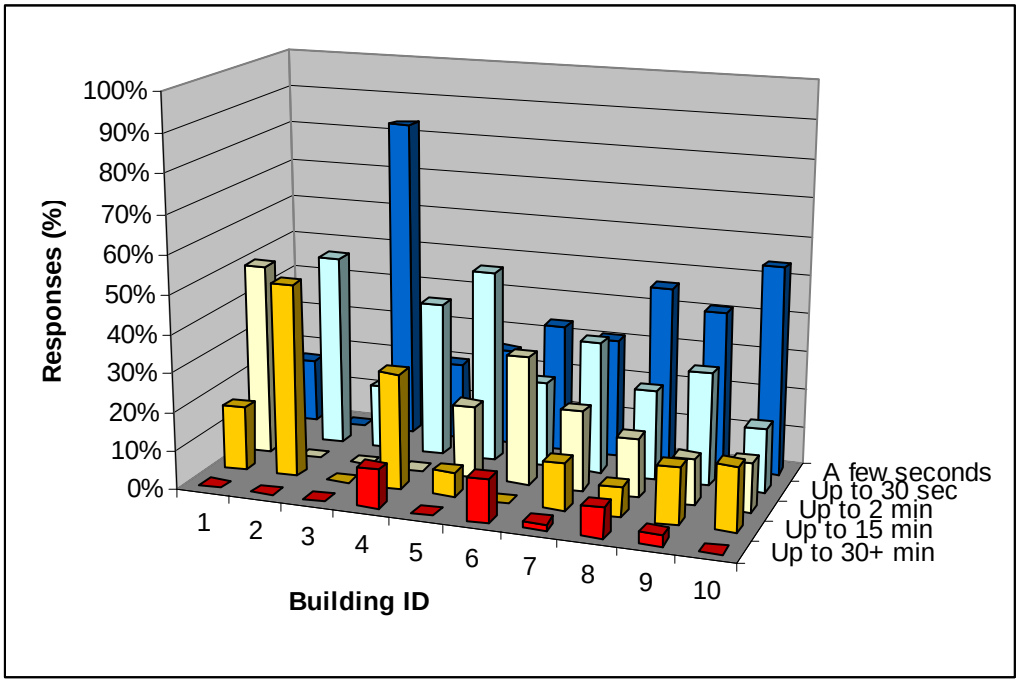


Figure P16. Specific responses on the occupant perception questionnaire when asked how long the distraction lasts after hearing sound/noise from outside of the building.

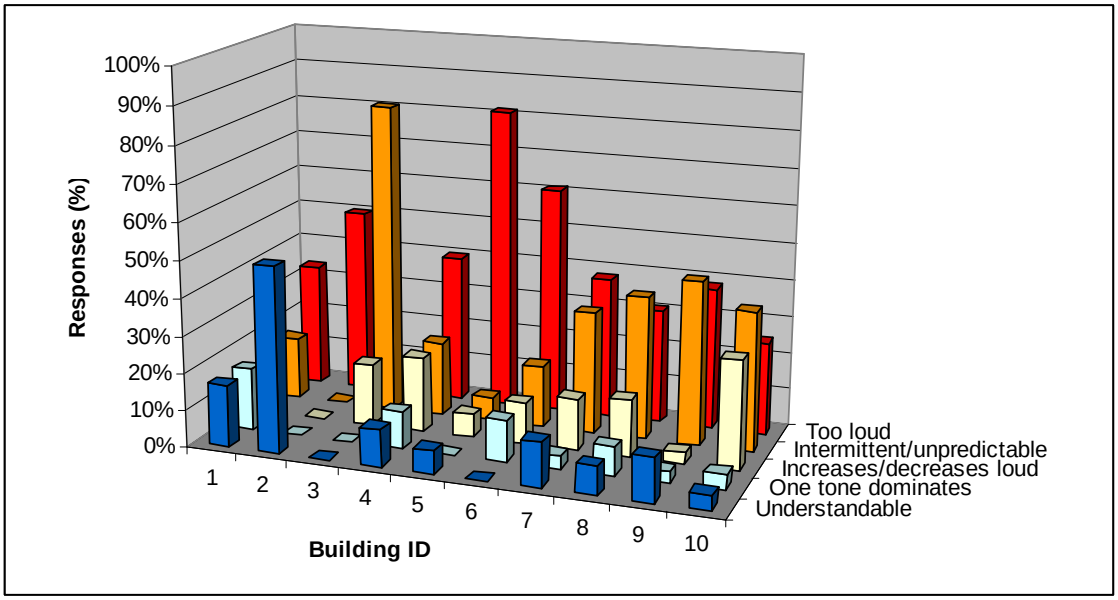


Figure P17. Specific responses on the occupant perception questionnaire when asked the reason that the noise from outside their building is distracting.

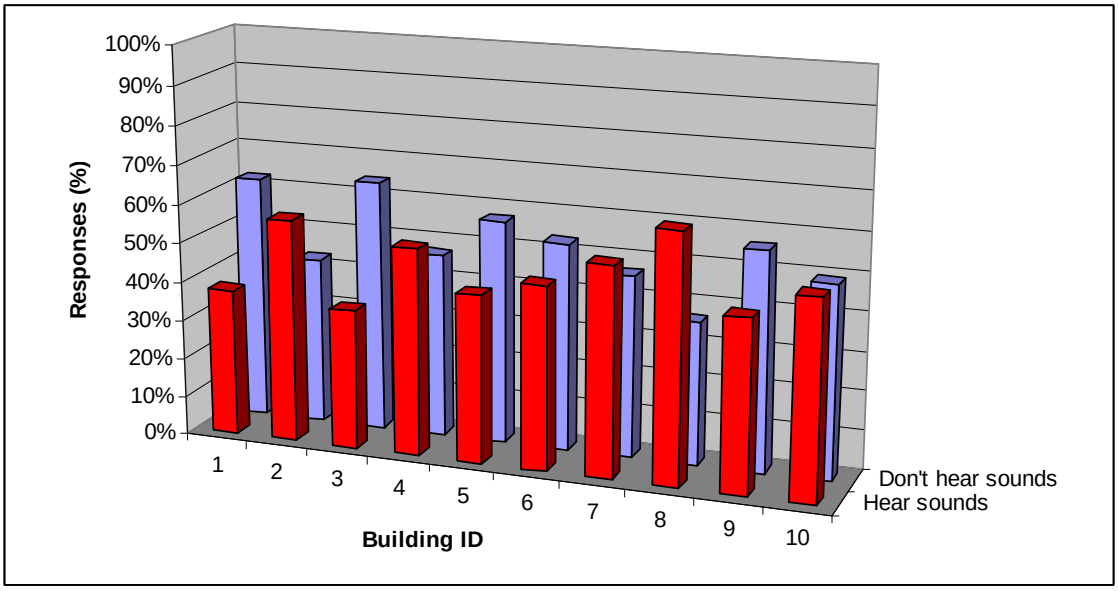


Figure P18. Summary of occupants' responses on the perception questionnaire concerning sounds from the telephone or speakerphone carrying into their work area.

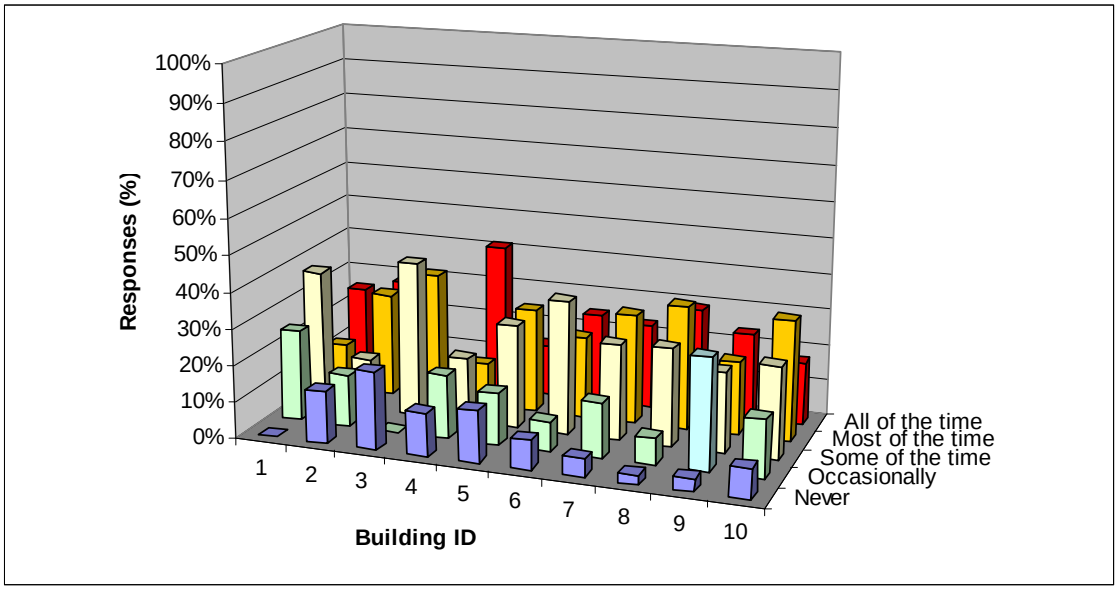


Figure P19. Specific responses on the occupant perception questionnaire when asked how often sounds from the telephone or speakerphone carry into their work area.

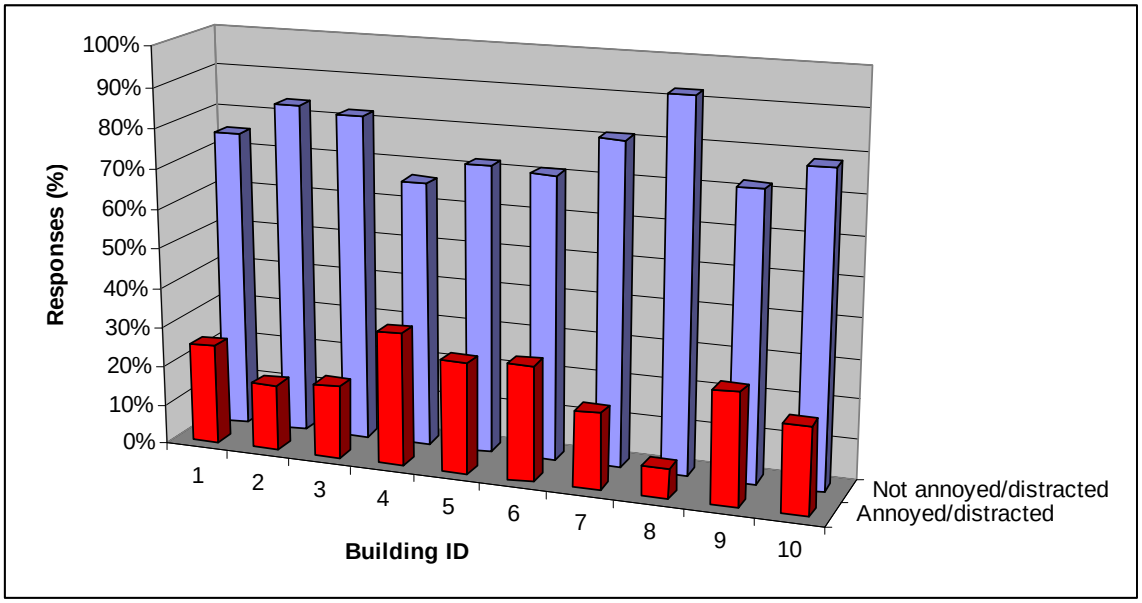


Figure P20. Summary of occupants' responses on the perception questionnaire concerning annoyance or distraction by sounds from the telephone or speakerphone that carry into their work area.

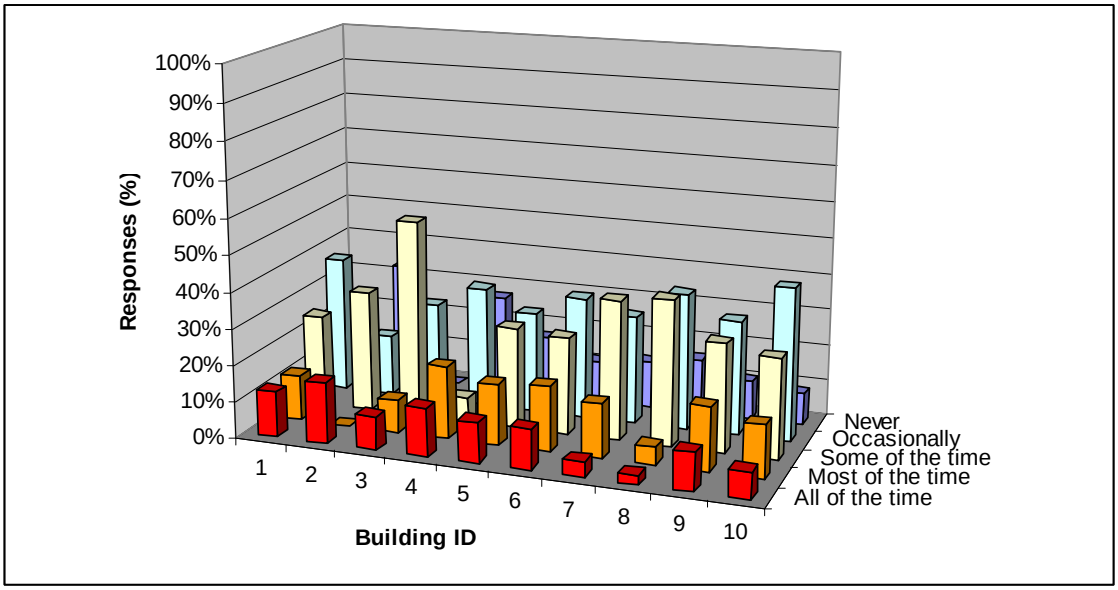


Figure P21. Specific responses on the occupant perception questionnaire when asked how often sounds from the telephone or speakerphone were annoying or distracting.

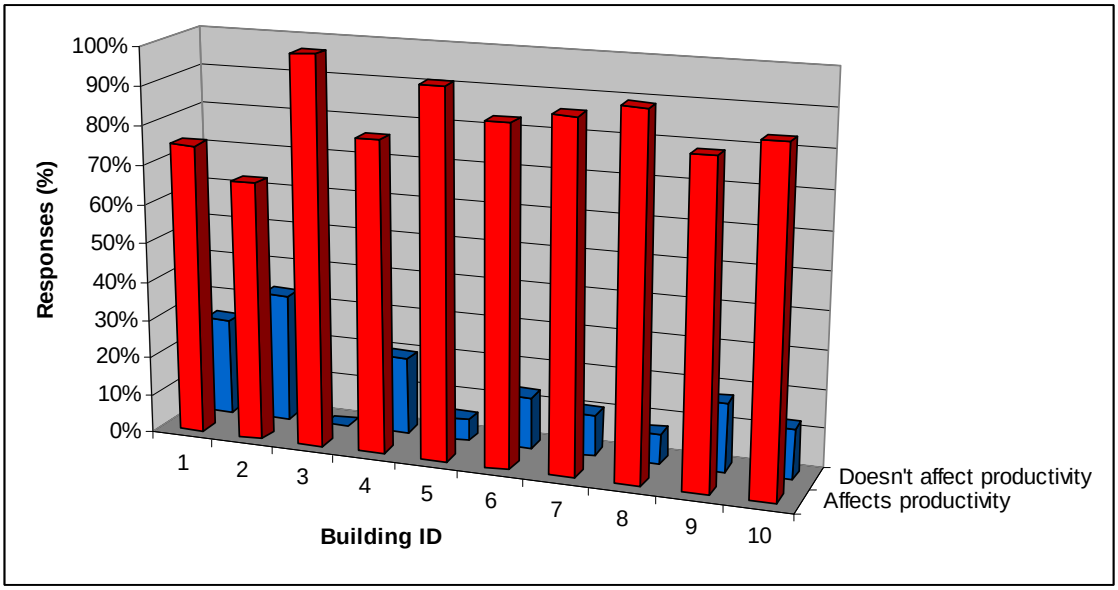


Figure P22. Summary of occupants' responses on the perception questionnaire concerning sounds from the telephone or speakerphone that carry into their work area affecting their productivity.

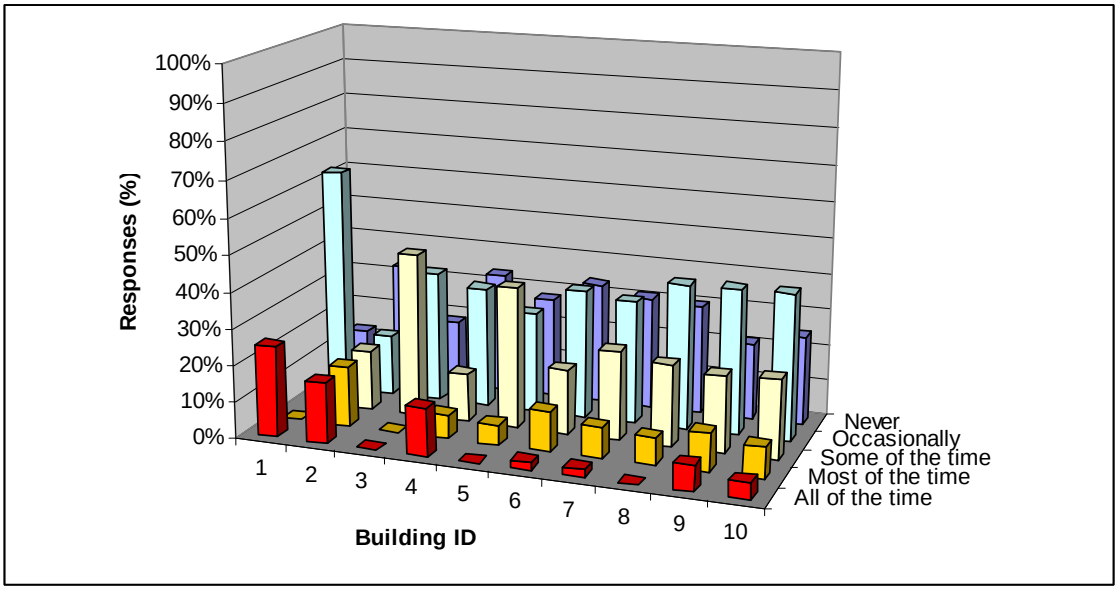


Figure P23. Specific responses on the occupant perception questionnaire when asked how often sounds from the telephone or speakerphone that carried into their work area affected their productivity.

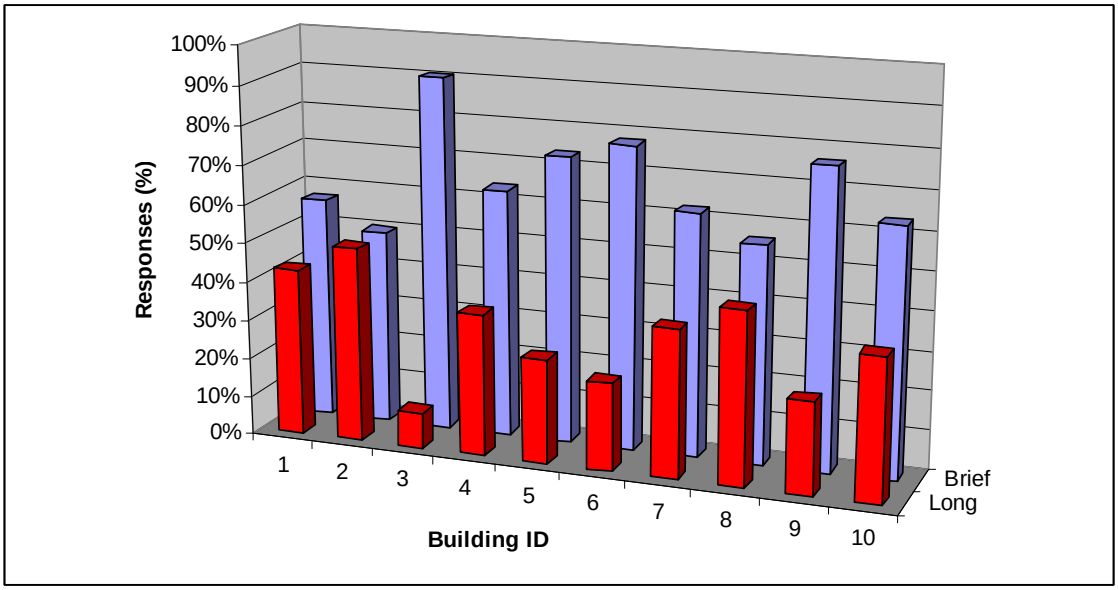


Figure P24. Summary of occupants' responses on the perception questionnaire concerning how quickly (brief or long period) they are distracted when sounds from the telephone or speakerphone are carried into their work area.

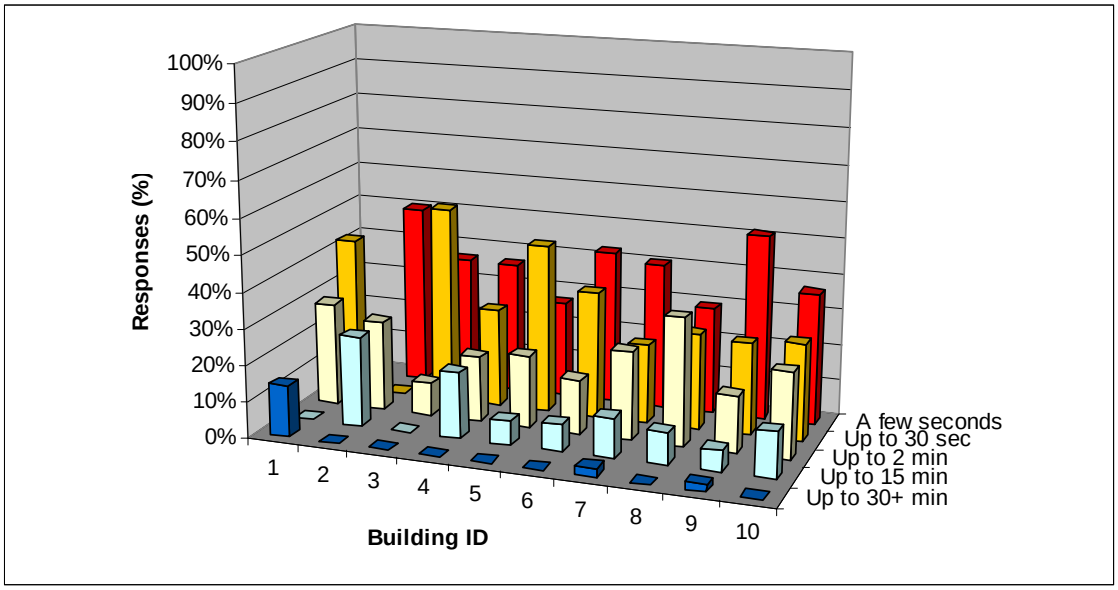


Figure P25. Specific responses on the occupant perception questionnaire when asked how quickly they are distracted when sounds from the telephone or speakerphone are carried into their work area.

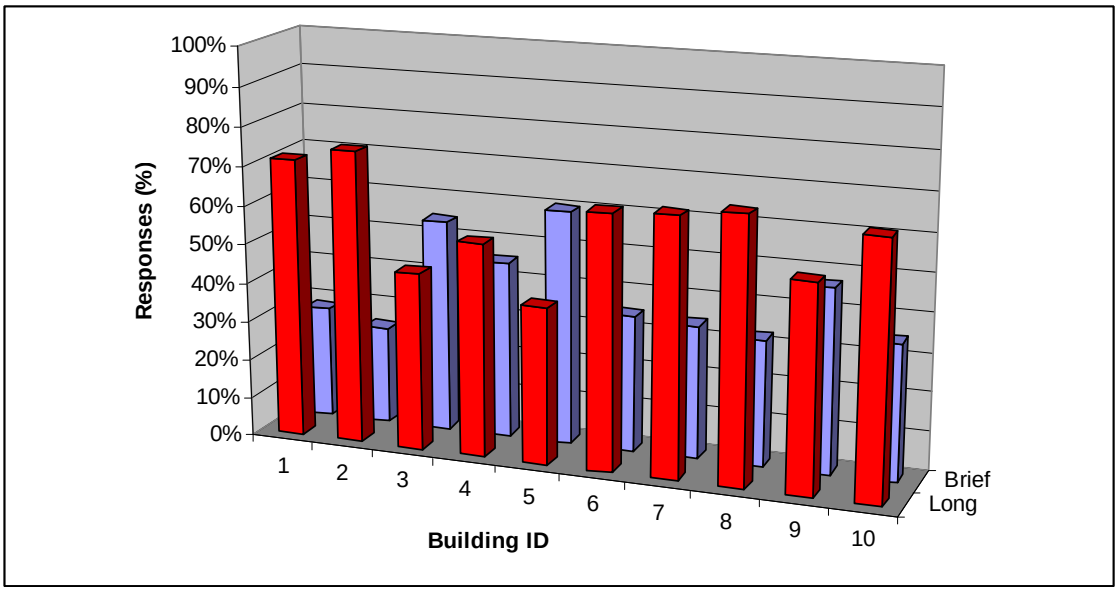


Figure P26. Summary of occupants' responses on the perception questionnaire concerning the length (brief or long period) sounds from the telephone or speakerphone were annoying or distracting.

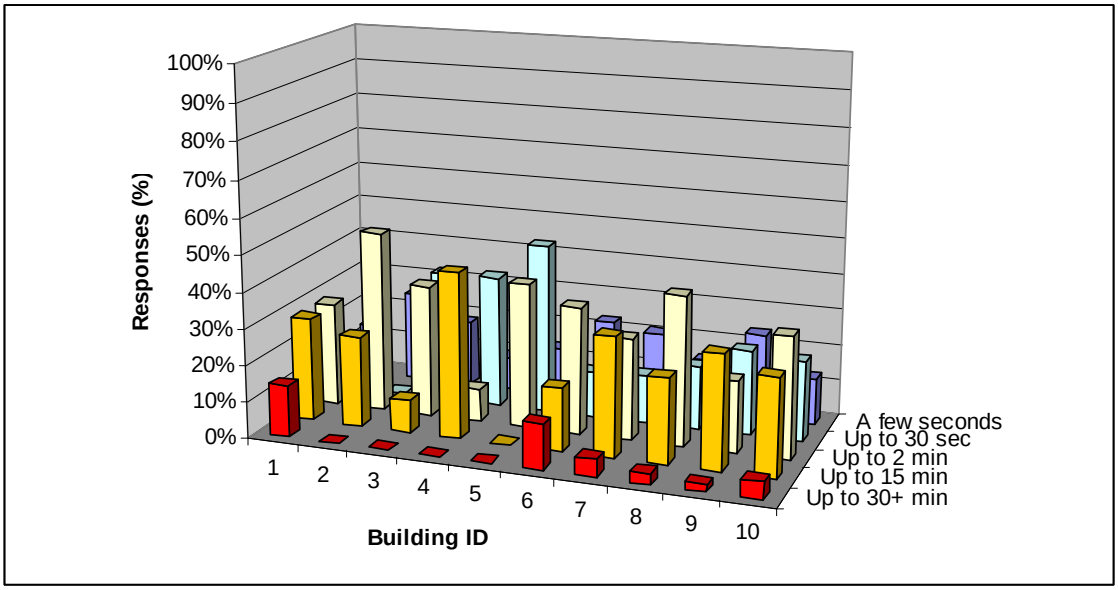


Figure P27. Specific responses on the occupant perception questionnaire when asked how long sounds from the telephone or speakerphone remained annoying or distracting.

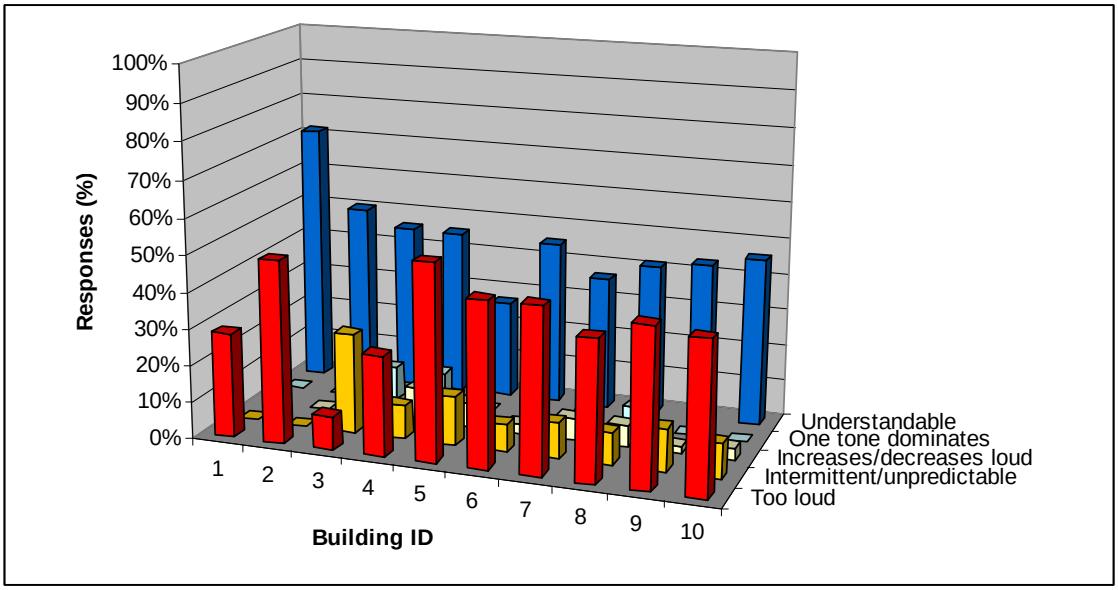


Figure P28. Specific responses on the occupant perception questionnaire when asked the reason that the sound/noise from the telephone or speakerphone is distracting.

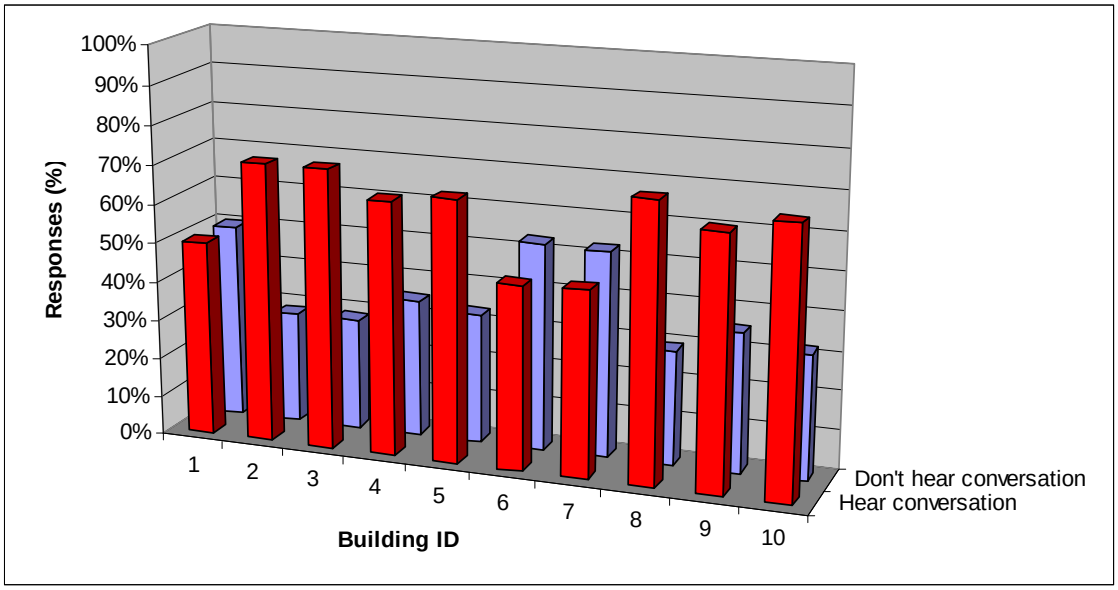


Figure P29. Summary of occupants' responses on the perception questionnaire concerning overhearing person-to-person conversations in their work area.

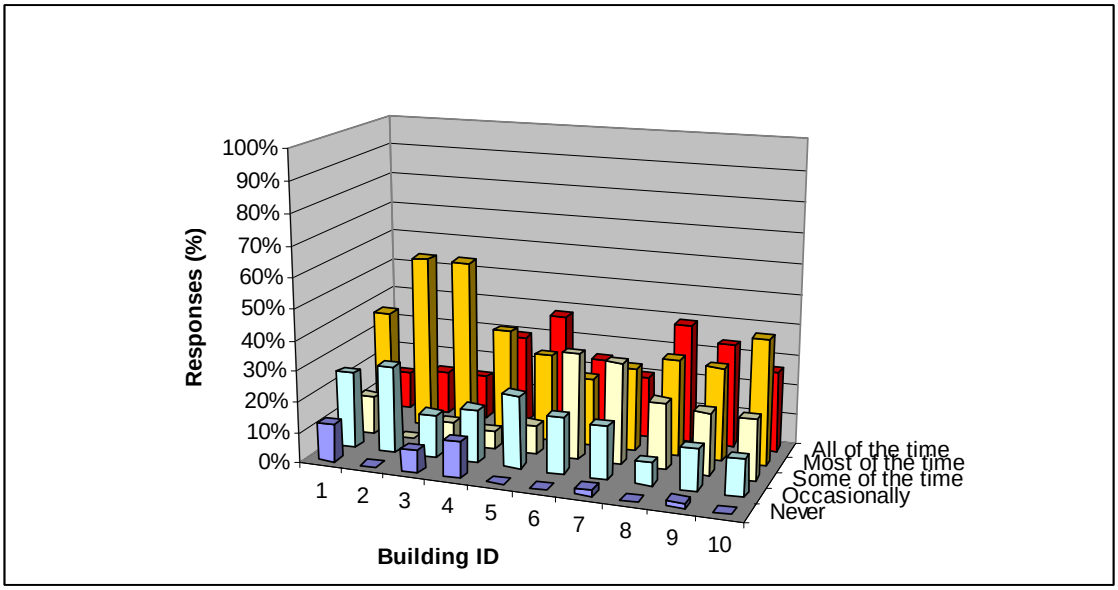


Figure P30. Specific responses on the occupant perception questionnaire when asked how often they overheard person-to-person conversations in their work area.

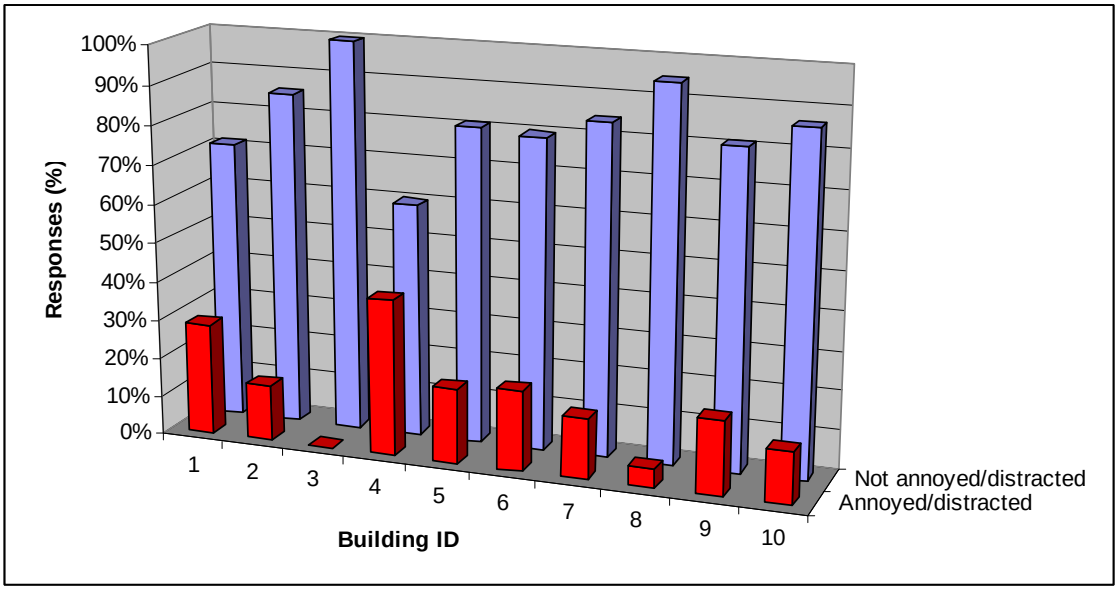


Figure P31. Summary of occupants' responses on the perception questionnaire concerning annoyance when overhearing person-to-person conversations in their work area.

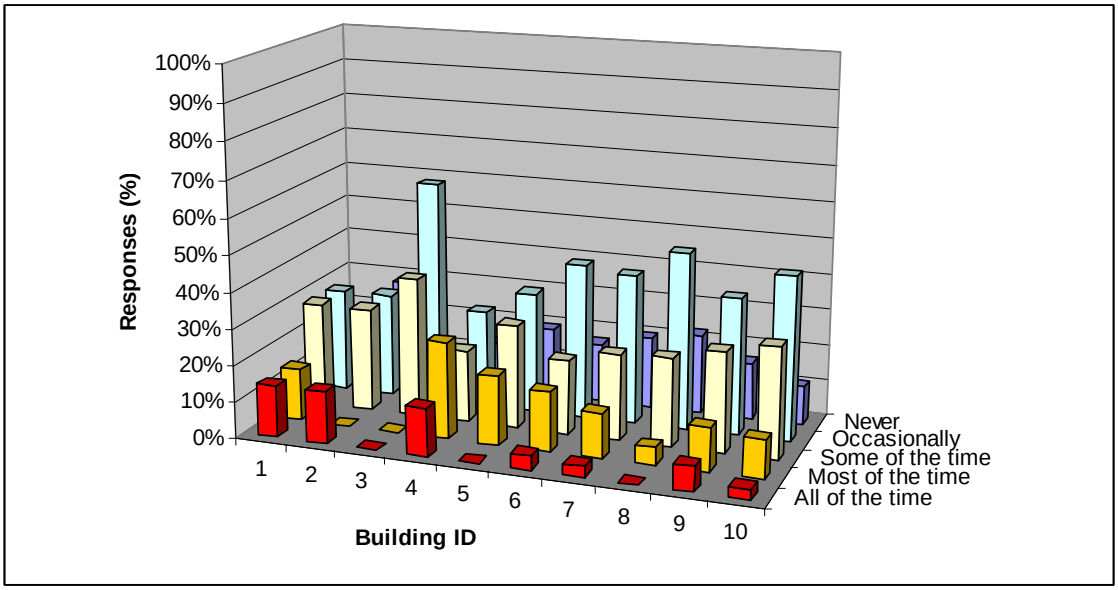


Figure P32. Specific responses on the occupant perception questionnaire when asked how often they are annoyed from overhearing person-to-person conversations in their work area.

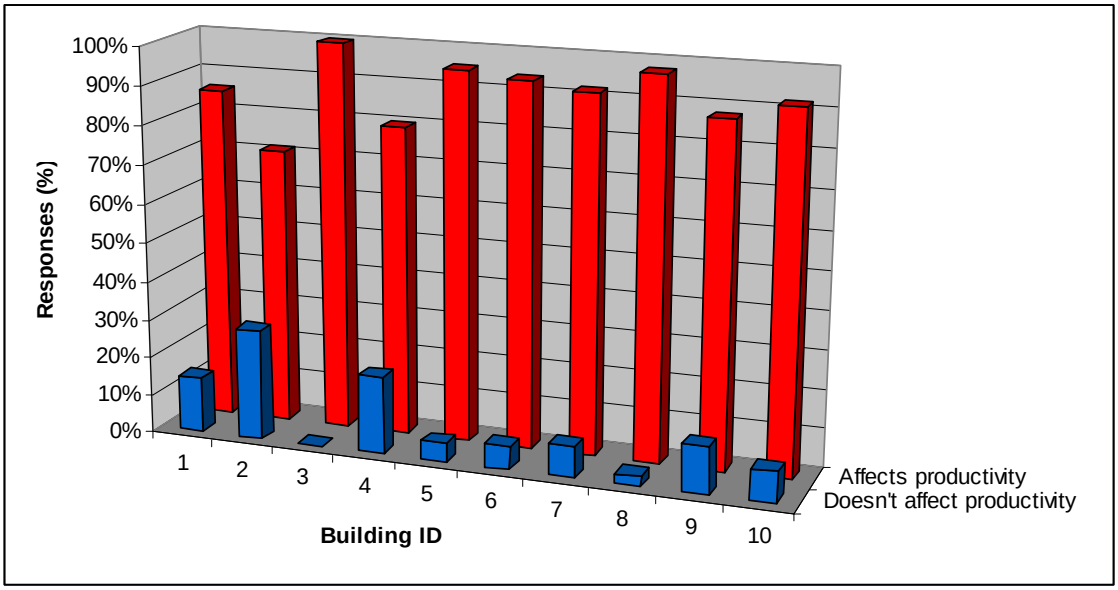


Figure P33. Summary of occupants' responses on the perception questionnaire concerning overhearing person-to-person conversations in their work area affecting productivity.

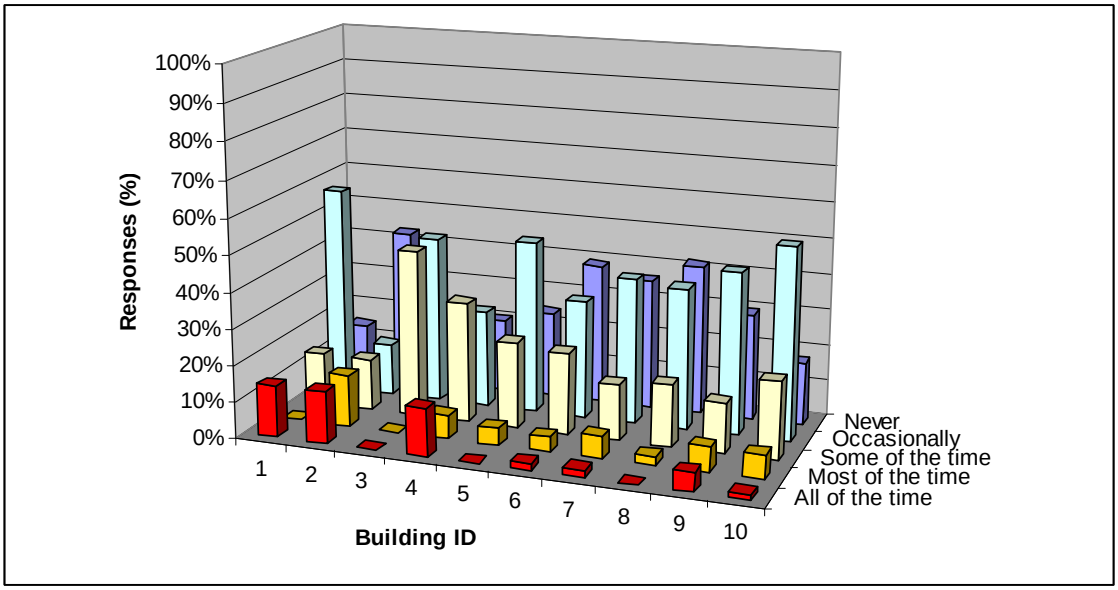


Figure P34. Specific responses on the occupant perception questionnaire when asked how often overhearing person-to-person conversations in their work area affected their productivity.

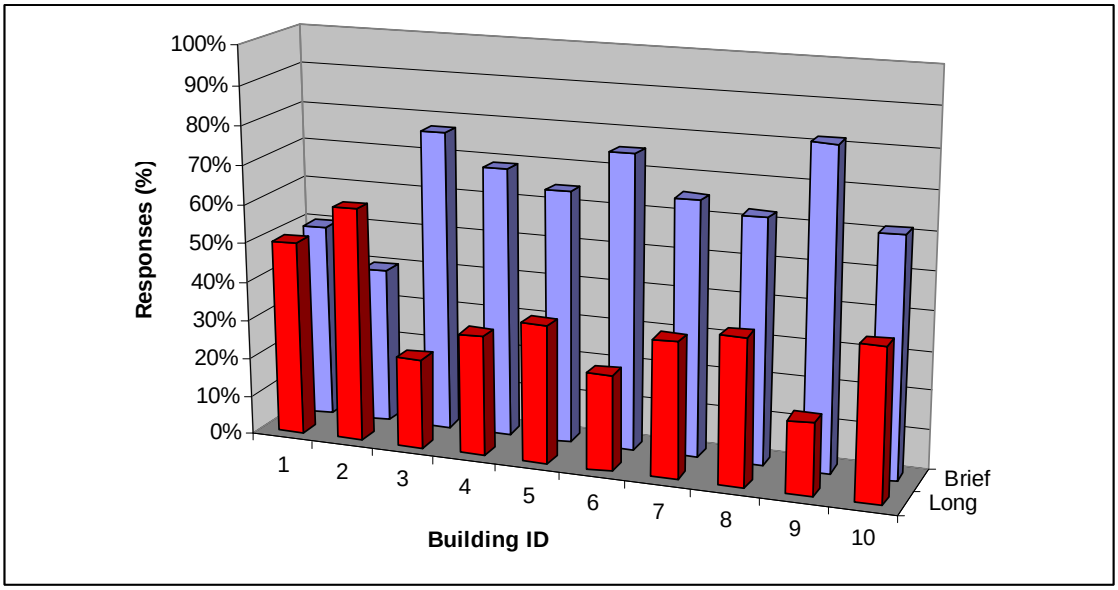


Figure P35. Summary of occupants' responses on the perception questionnaire concerning how soon (brief or long period) overhearing person-to-person conversations in their work area affected their productivity.

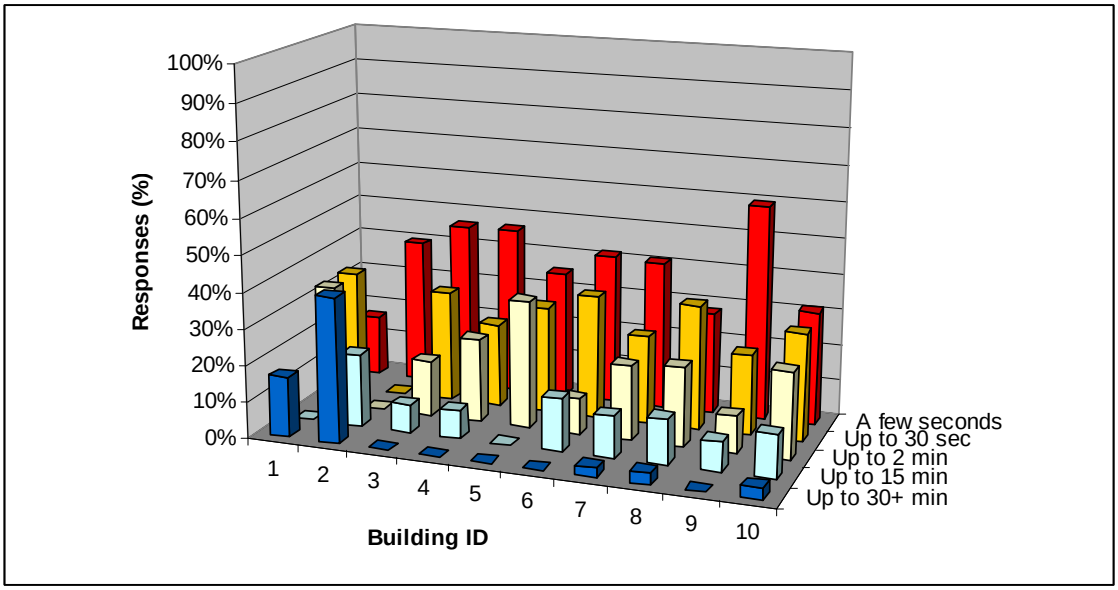


Figure P36. Specific responses on the occupant perception questionnaire when asked how quickly overhearing person-to-person conversations in their work area affected their productivity.

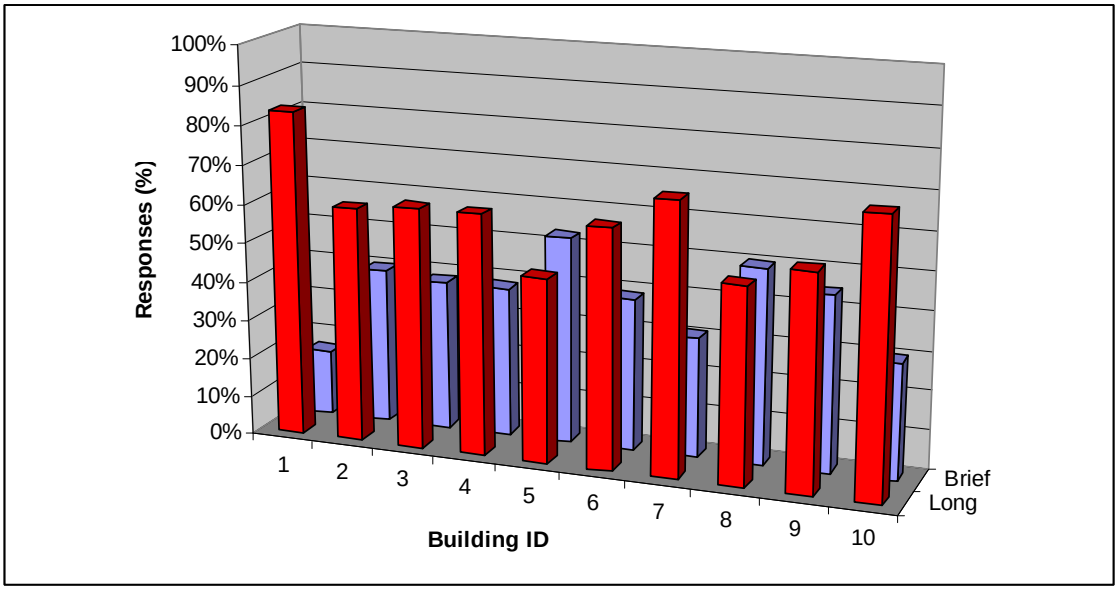


Figure P37. Summary of occupants' responses on the perception questionnaire concerning the length of the disruption (brief or long) from overhearing person-to-person conversations in their work area.

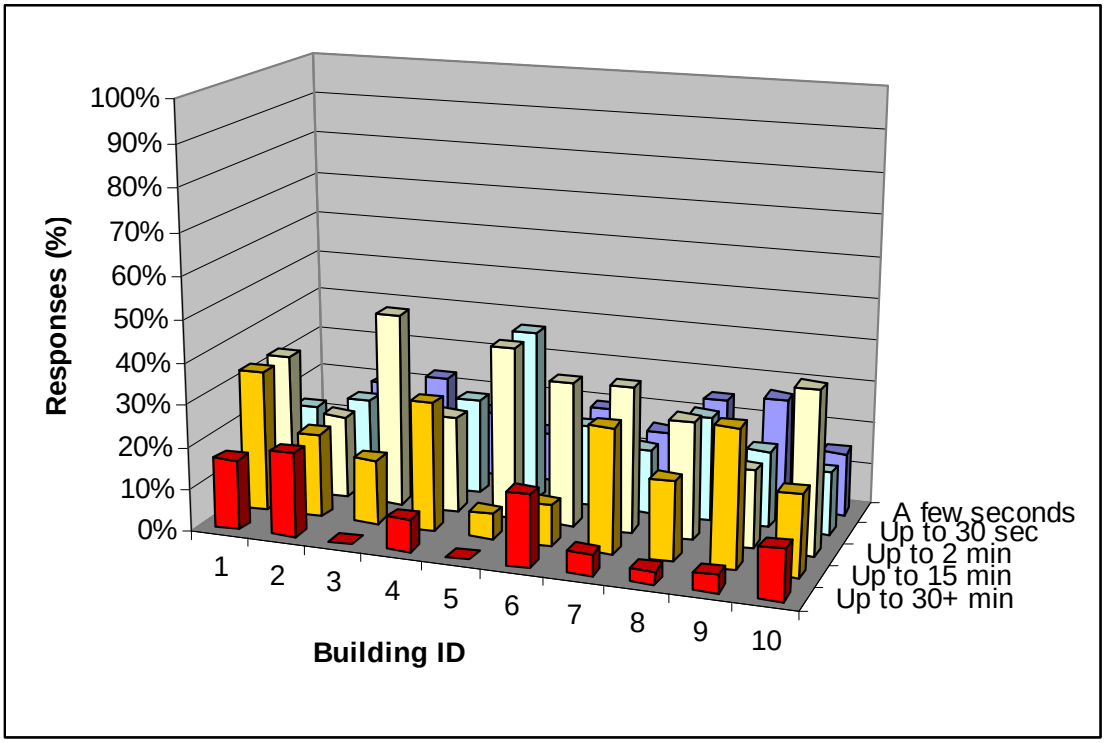


Figure P38. Specific responses on the occupant perception questionnaire when asked how long the disruption due to overhearing person-to-person conversations in their work area lasted.

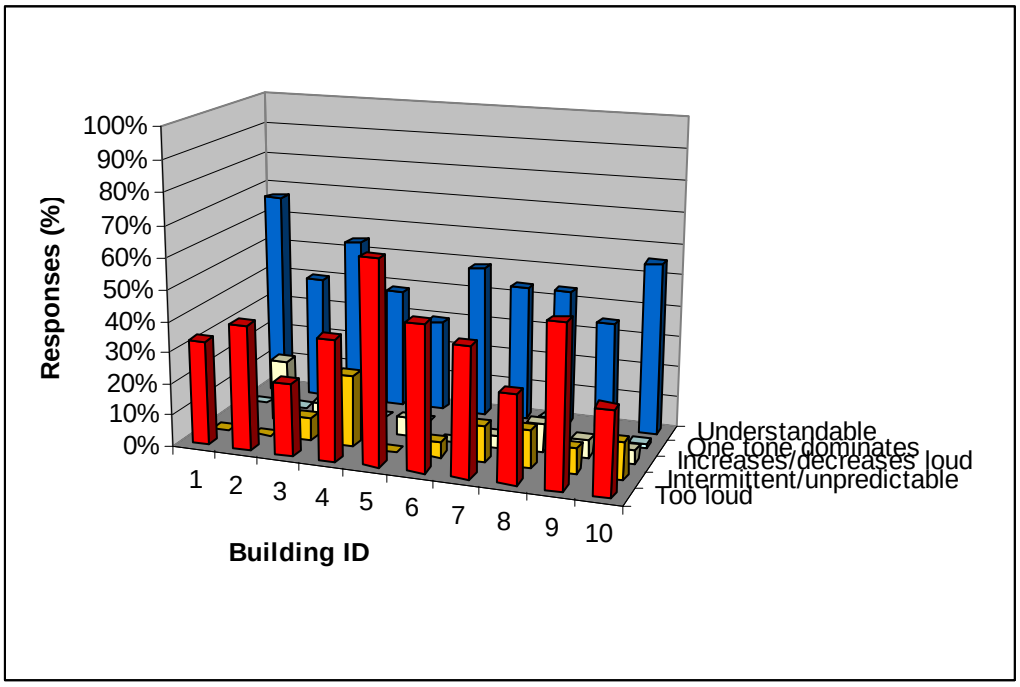


Figure P39. Specific responses on the occupant perception questionnaire when asked the reason that the noise from overhearing person-to-person conversations is distracting.

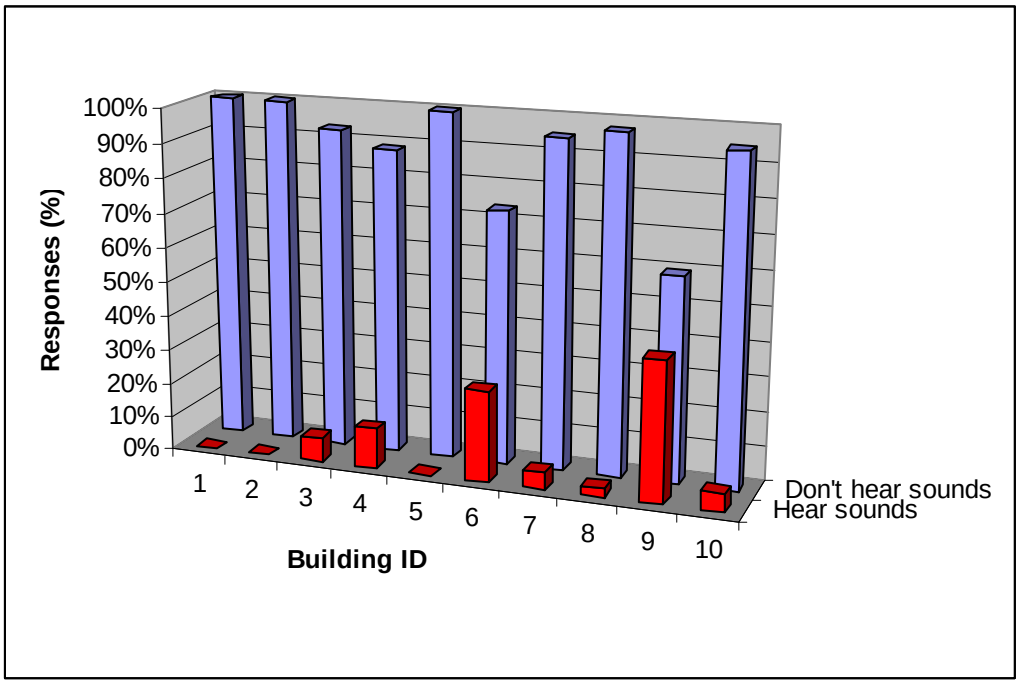


Figure P40. Summary of occupants' responses on the perception questionnaire concerning hearing sounds of music or masking while in their work area.

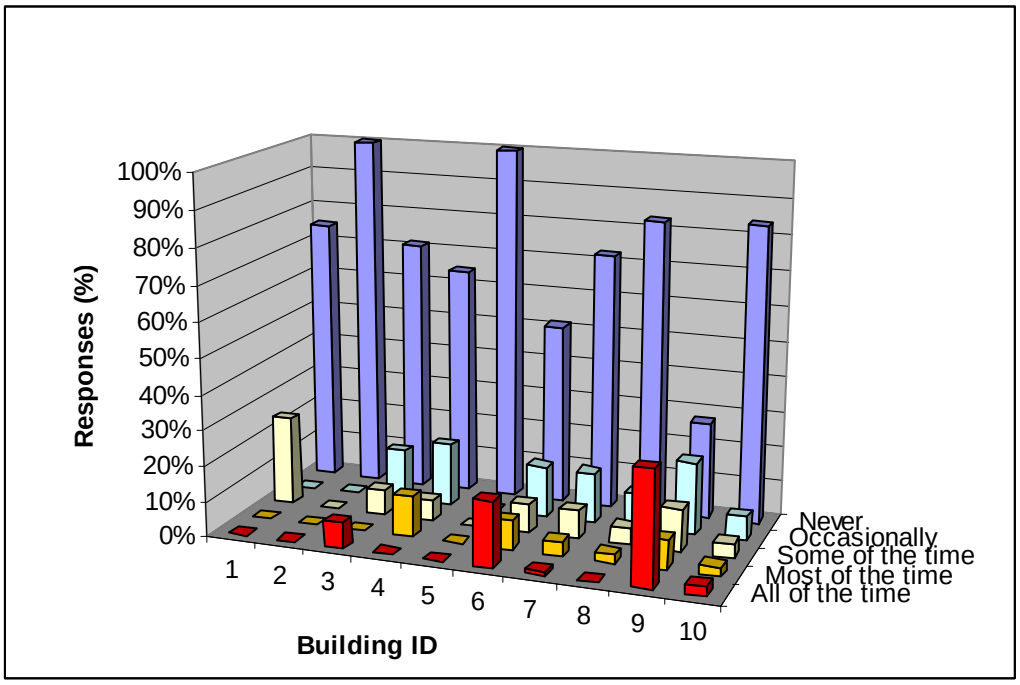


Figure P41. Specific responses on the occupant perception questionnaire when asked how often they could hear sounds of music or masking while in their work area.

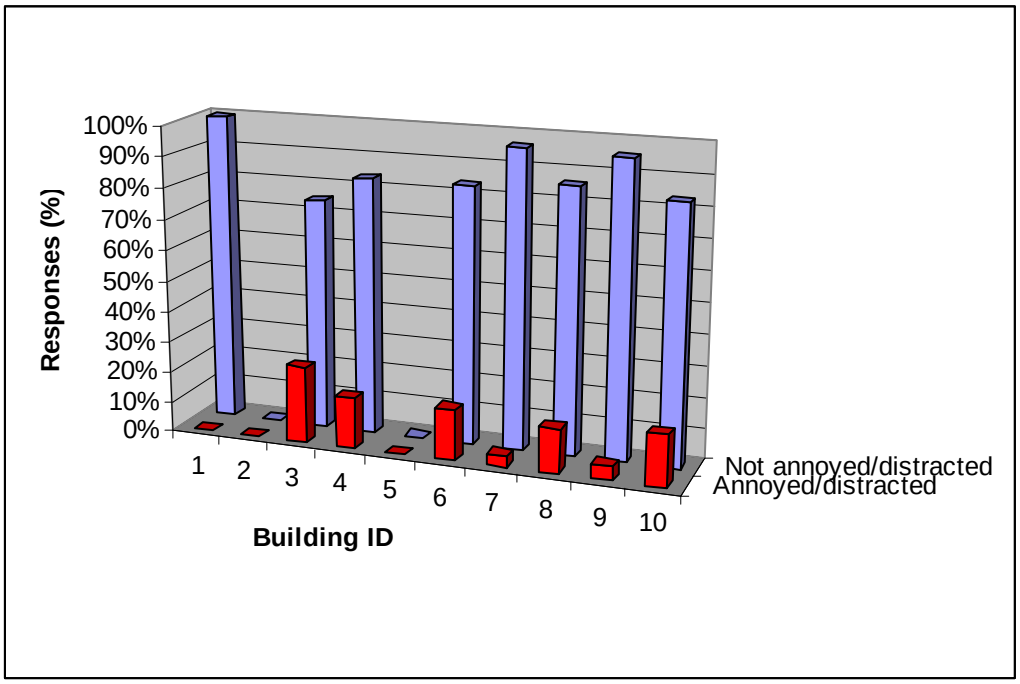


Figure P42. Summary of occupants' responses on the perception questionnaire concerning annoyance or distraction due to the hearing sounds of music while in their work area. No responses on this question at 2 buildings.

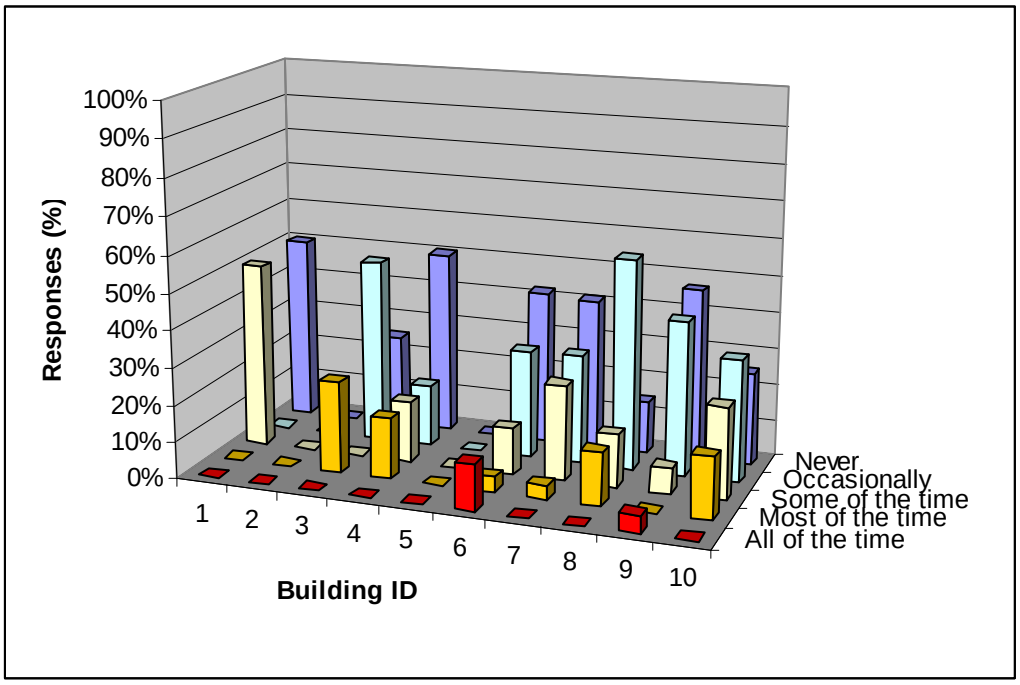


Figure P43. Specific responses on the occupant perception questionnaire when asked if hearing sounds of music while in their work area was annoying or distracting.

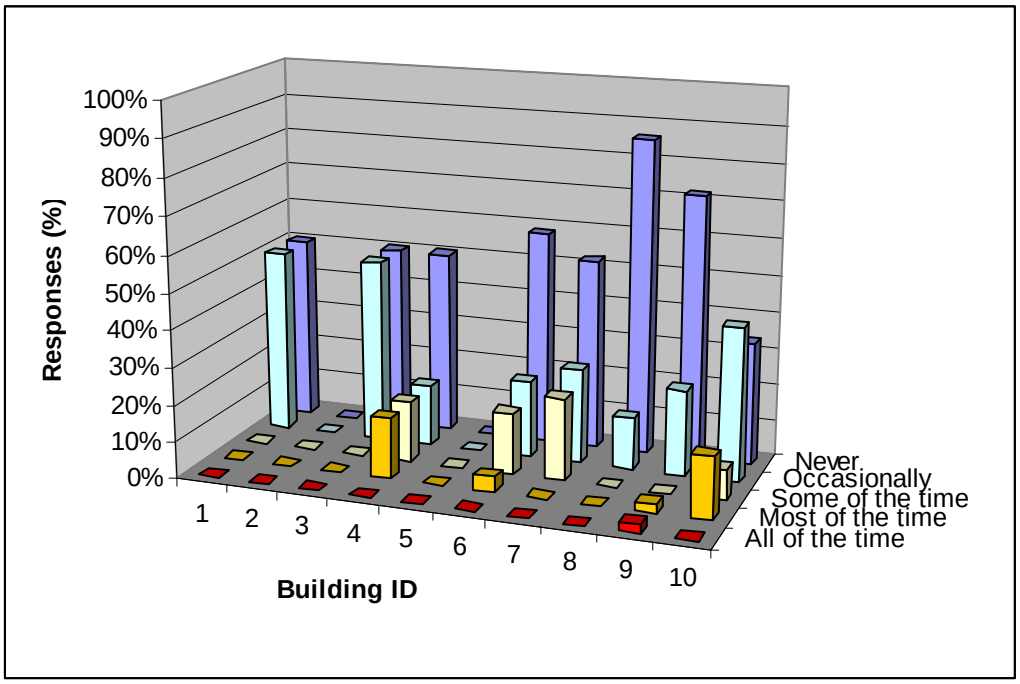


Figure P44. Specific responses on the occupant perception questionnaire when asked how often hearing sounds of music while in their work area adversely affected their productivity.

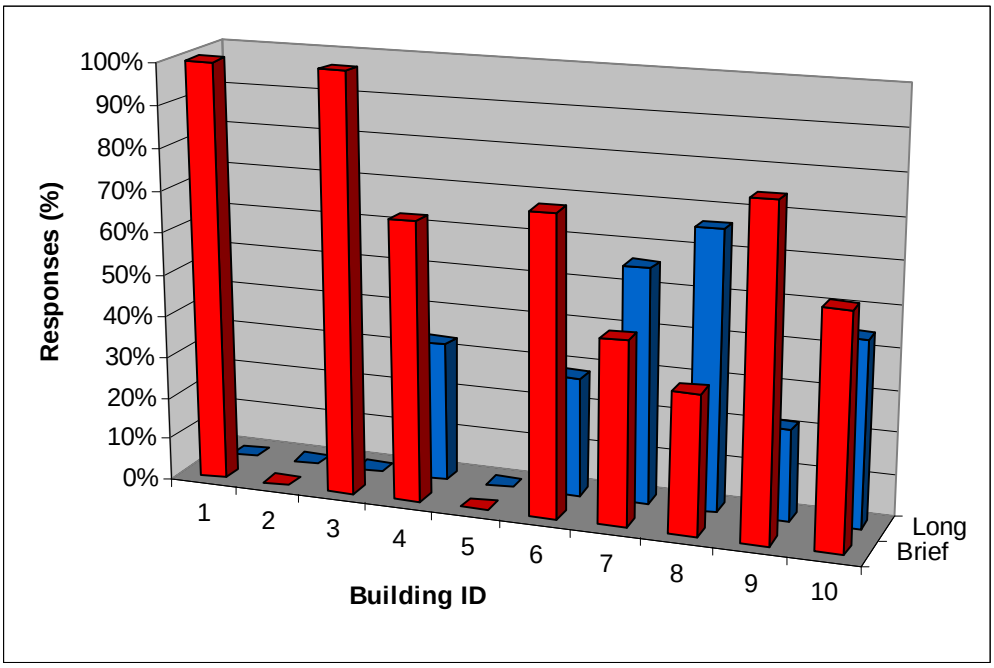


Figure P45. Summary of occupants' responses on the perception questionnaire concerning how quickly (brief or long period) after hearing the sound of music it is distracting.

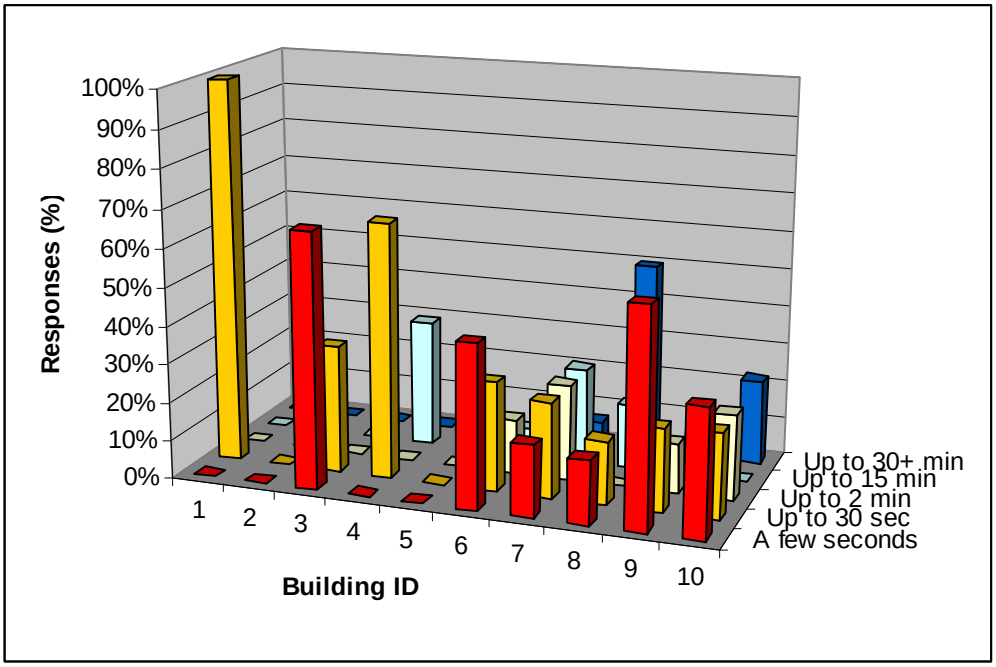


Figure P46. Specific responses on the occupant perception questionnaire when asked how quickly the sound of music is distracting.

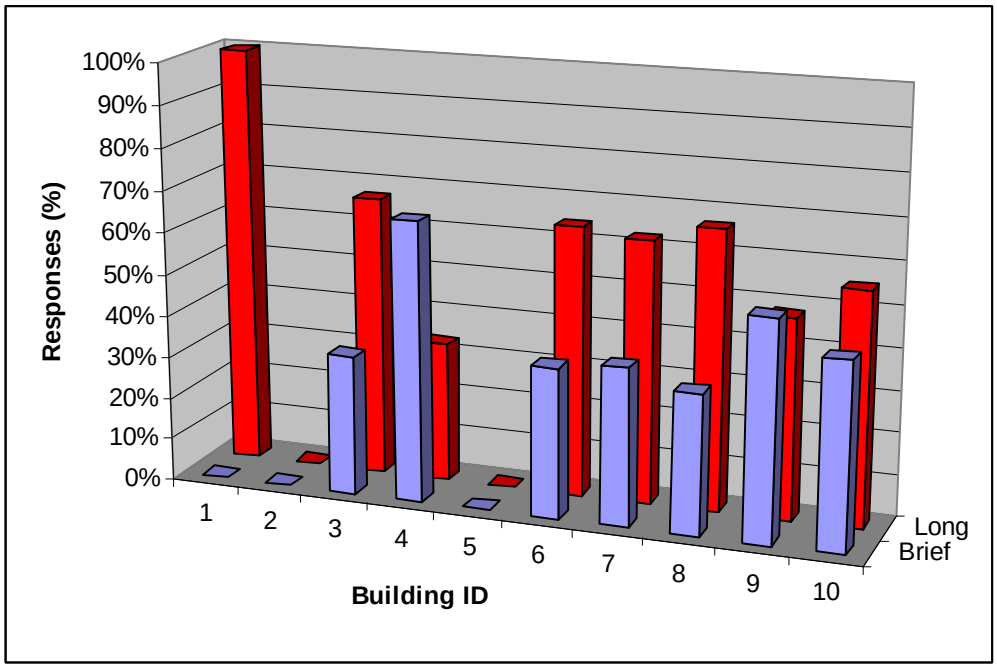


Figure P47. Summary of occupants' responses on the perception questionnaire concerning how long a duration (brief or long period) the sound of music is distracting.

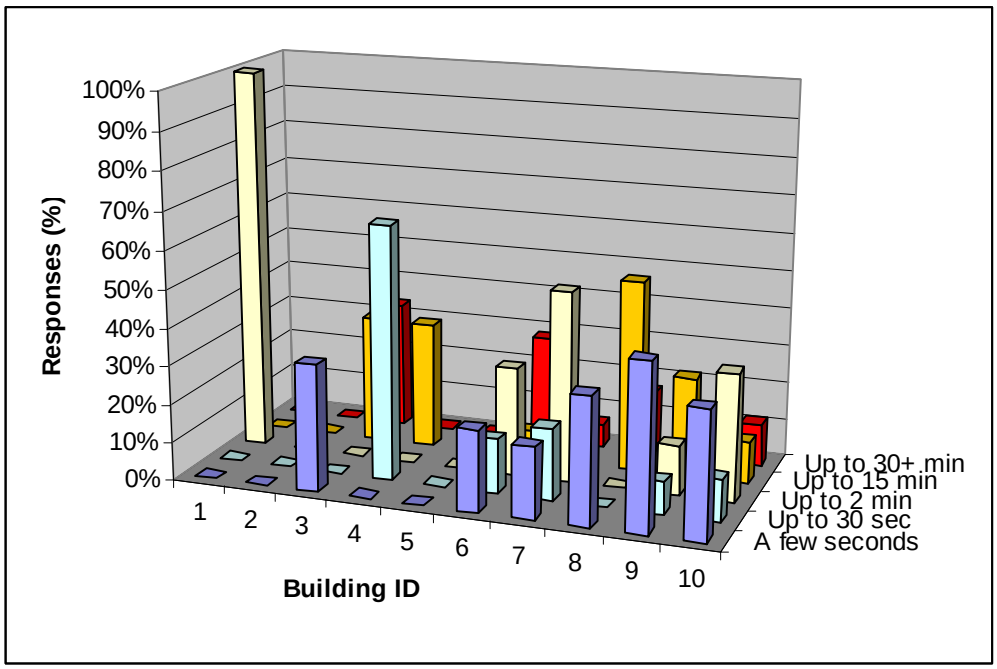


Figure P48. Specific responses on the occupant perception questionnaire when asked how long a duration the sound of music is distracting.

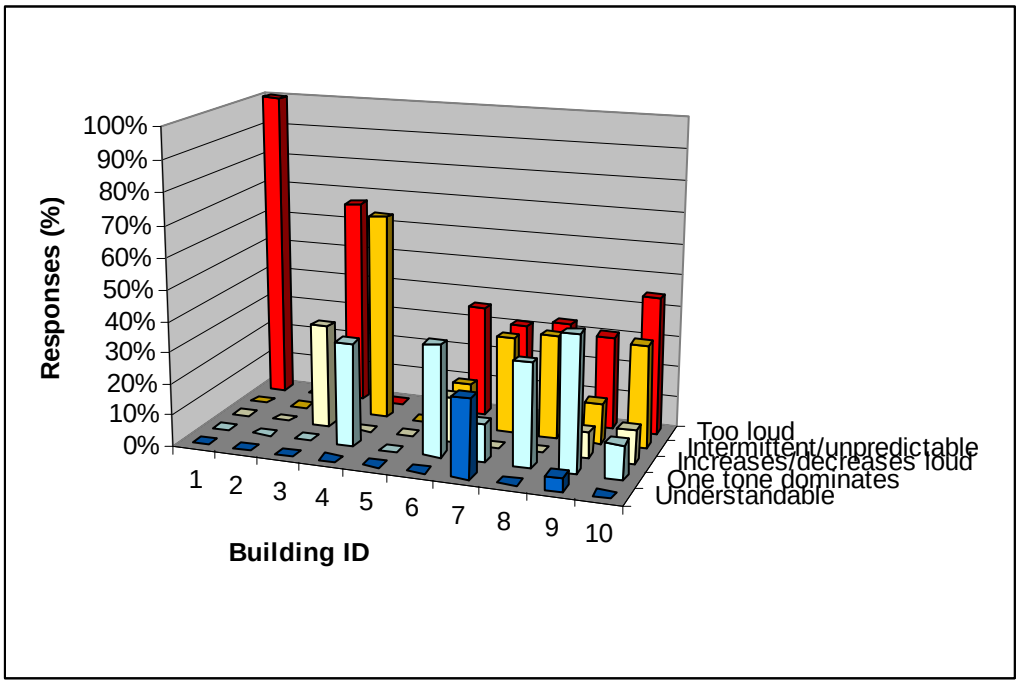


Figure P49. Specific responses on the occupant perception questionnaire when asked the reason that the music is distracting.

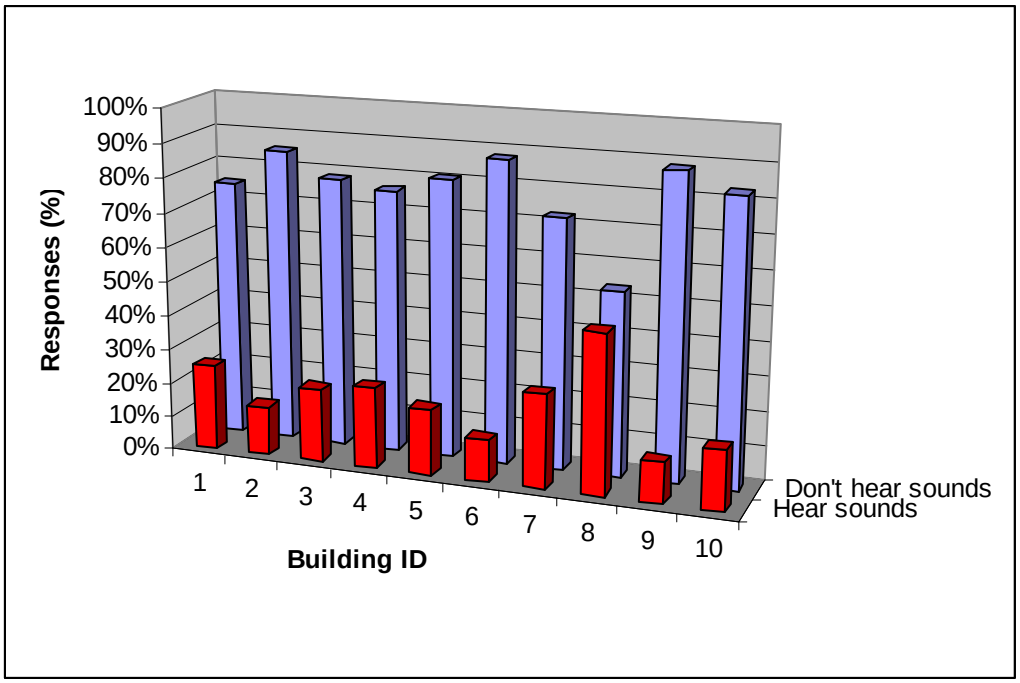


Figure P50. Summary of occupants' responses on the perception questionnaire concerning hearing of sounds from the equipment in the building.

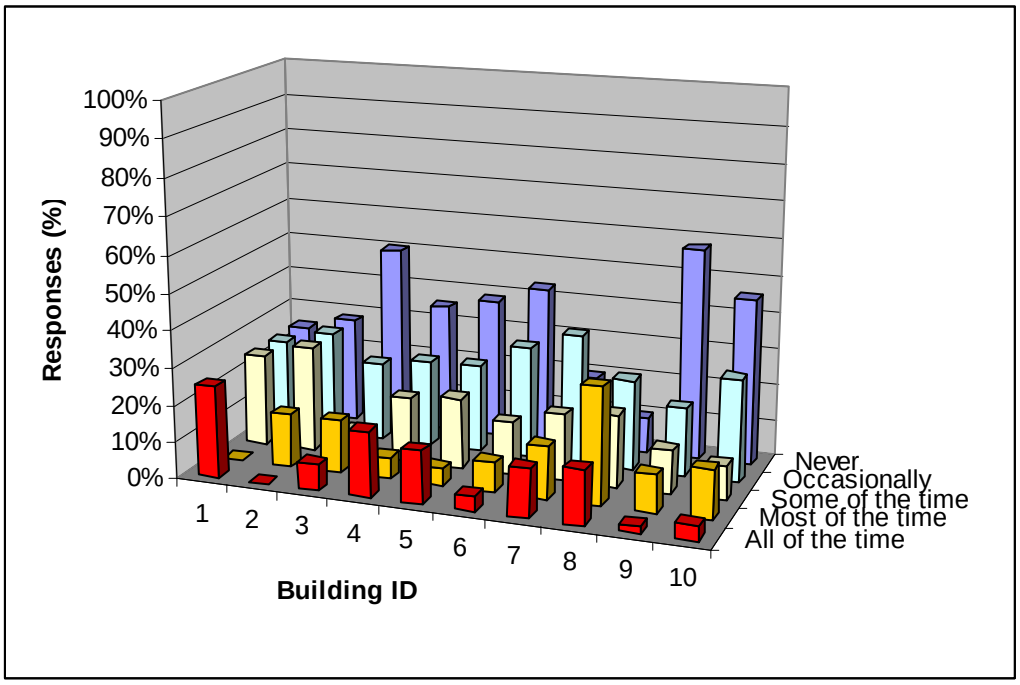


Figure P51. Specific responses on the occupant perception questionnaire when asked about the hearing of sounds from the equipment in the building.

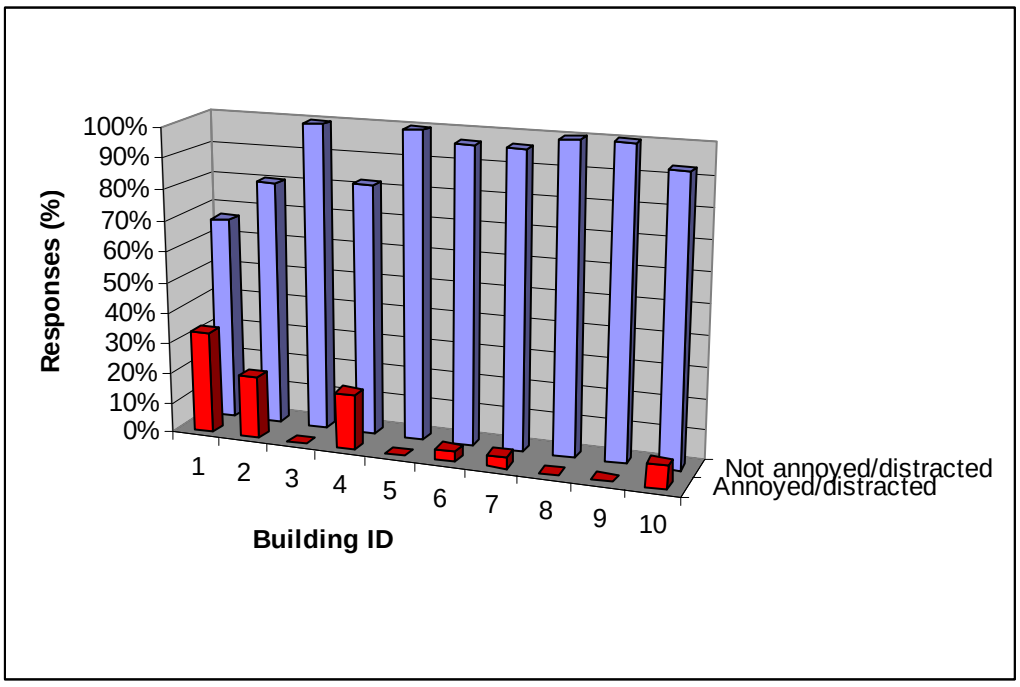


Figure P52. Summary of occupants' responses on the perception questionnaire concerning annoyance/distraction caused by the hearing of sounds from the equipment in the building.

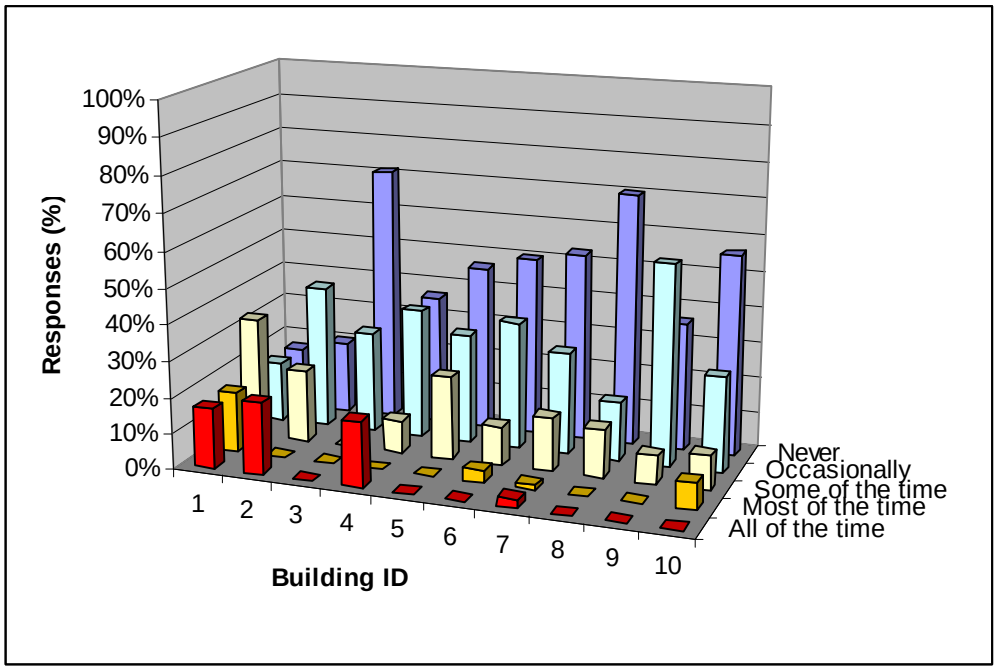


Figure P53. Specific responses on the occupant perception questionnaire when asked how often there was annoyance/distraction caused by the hearing of sounds from the equipment in the building.

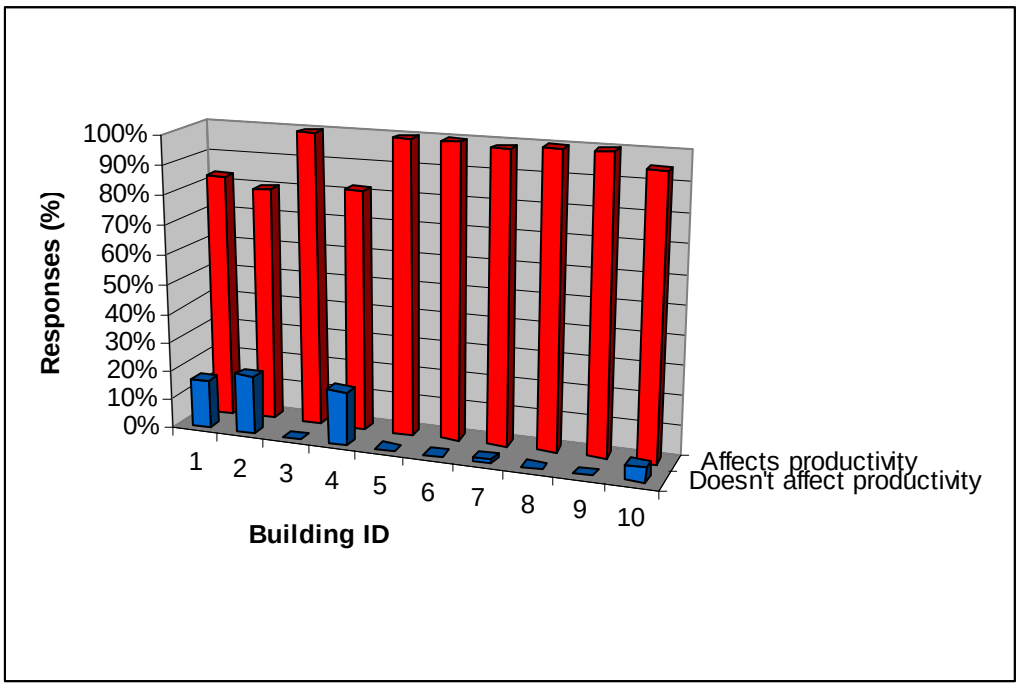


Figure P54. Summary of occupants' responses on the perception questionnaire concerning the hearing of sounds from the equipment in the building affecting productivity.

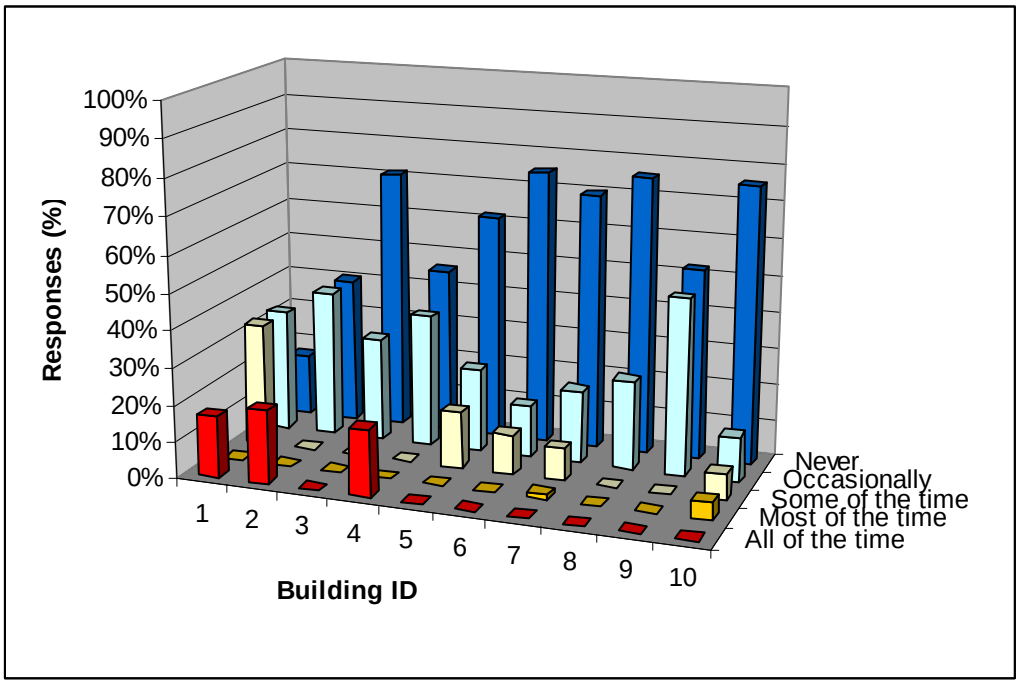


Figure P55. Specific responses on the occupant perception questionnaire when asked if the hearing of sounds from the equipment in the building affected productivity.

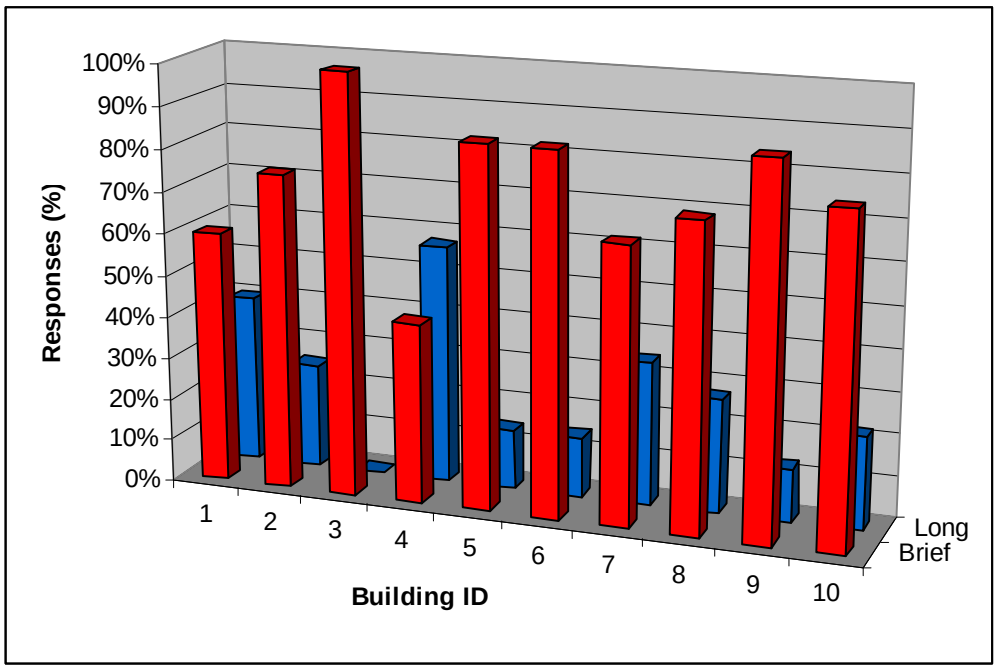


Figure P56. Summary of occupants' responses on the perception questionnaire concerning how quickly (brief or long period) the hearing of sounds from the equipment in the building is distracting.

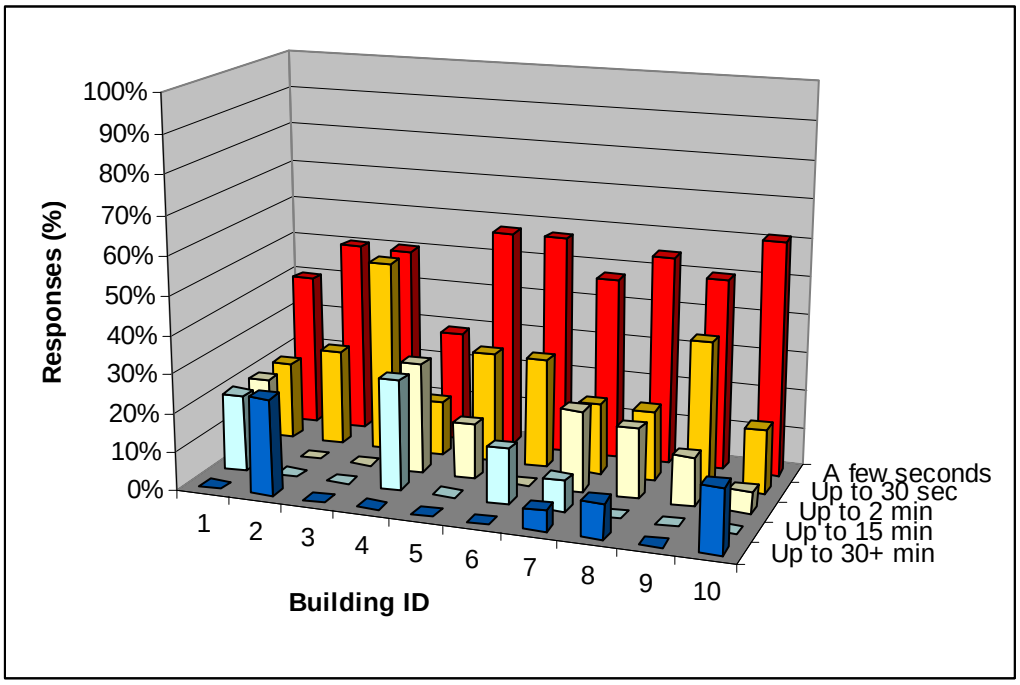


Figure P57. Specific responses on the occupant perception questionnaire when asked how quickly the hearing of sounds from the equipment in the building is distracting.

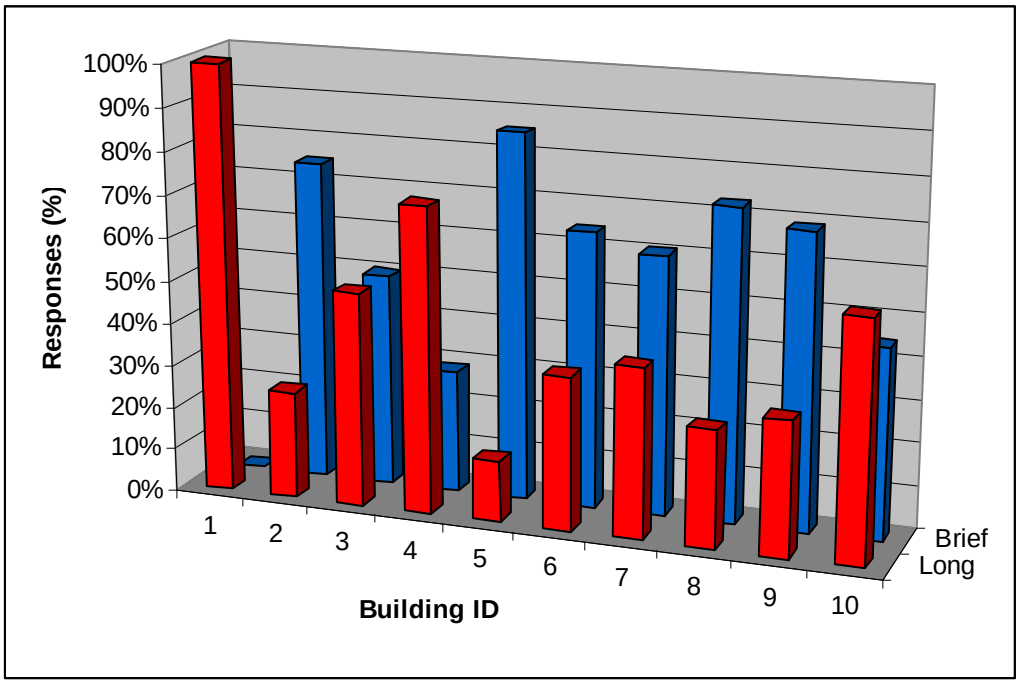


Figure P58. Summary of occupants' responses on the perception questionnaire concerning how long (brief or long period) the hearing of sounds from the equipment in the building is distracting.

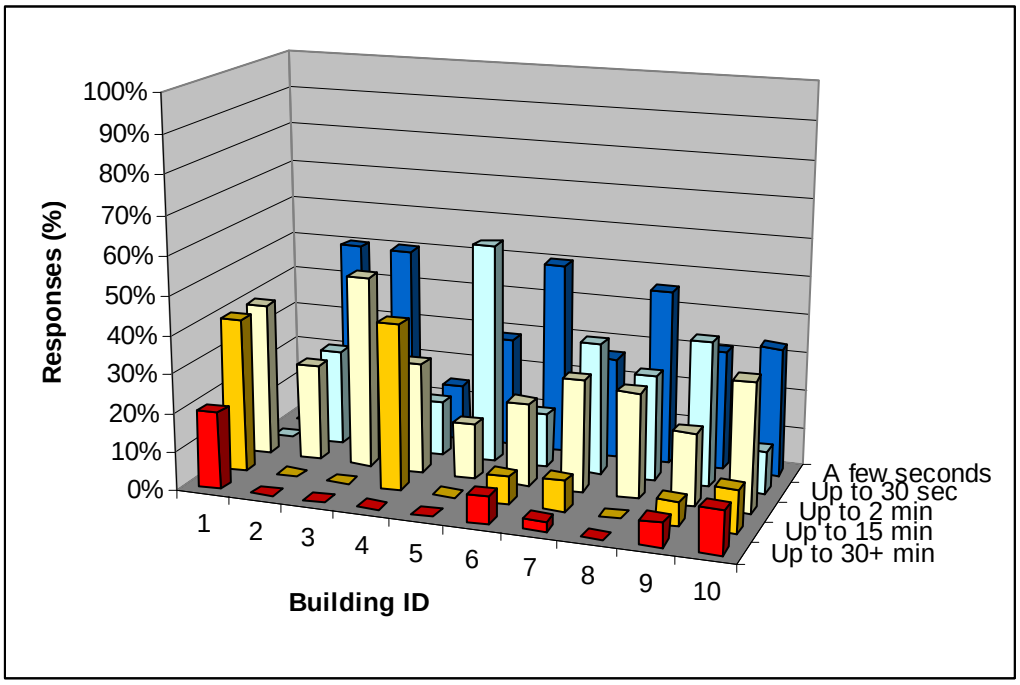


Figure P59. Specific responses on the occupant perception questionnaire when asked how long the hearing of sounds from the equipment in the building is distracting.

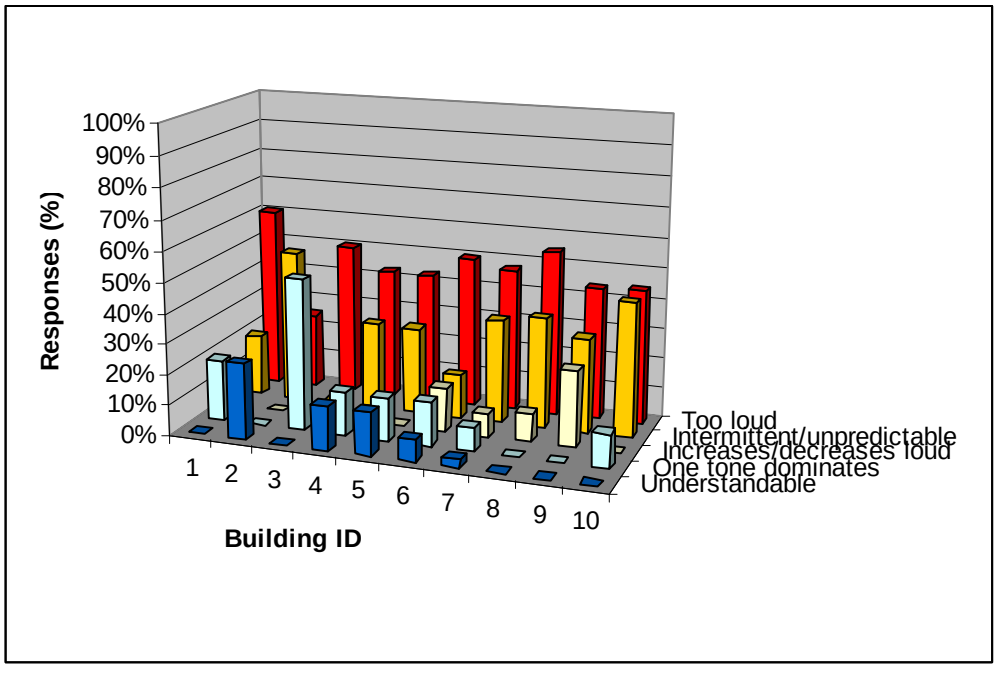


Figure P60. Specific responses on the occupant perception questionnaire when asked the cause of the distraction from hearing of sounds from office equipment in the building.

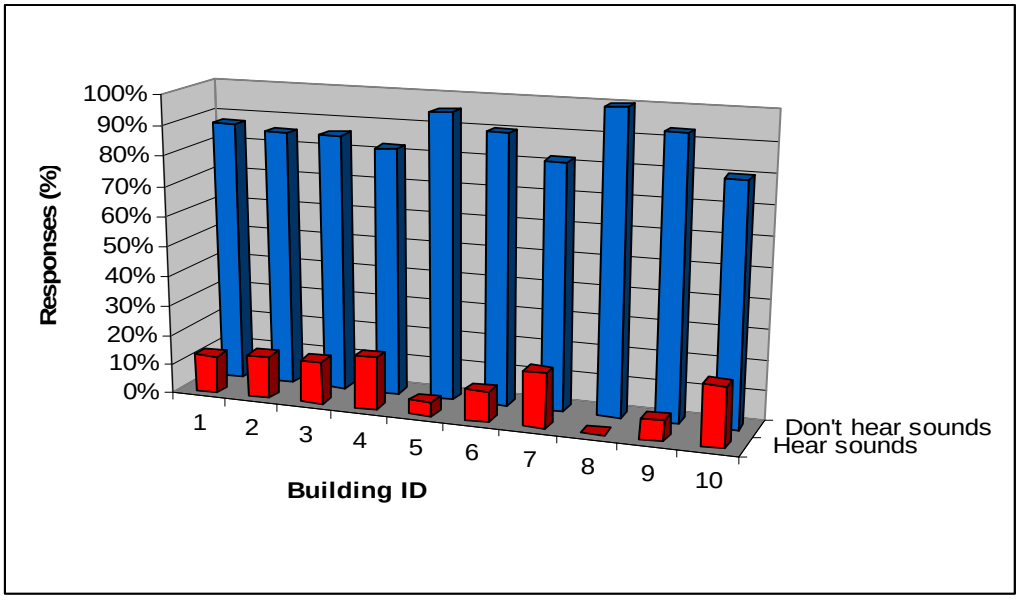


Figure P61. Summary of occupants' responses on the perception questionnaire concerning hearing sound of mechanical equipment in the building.

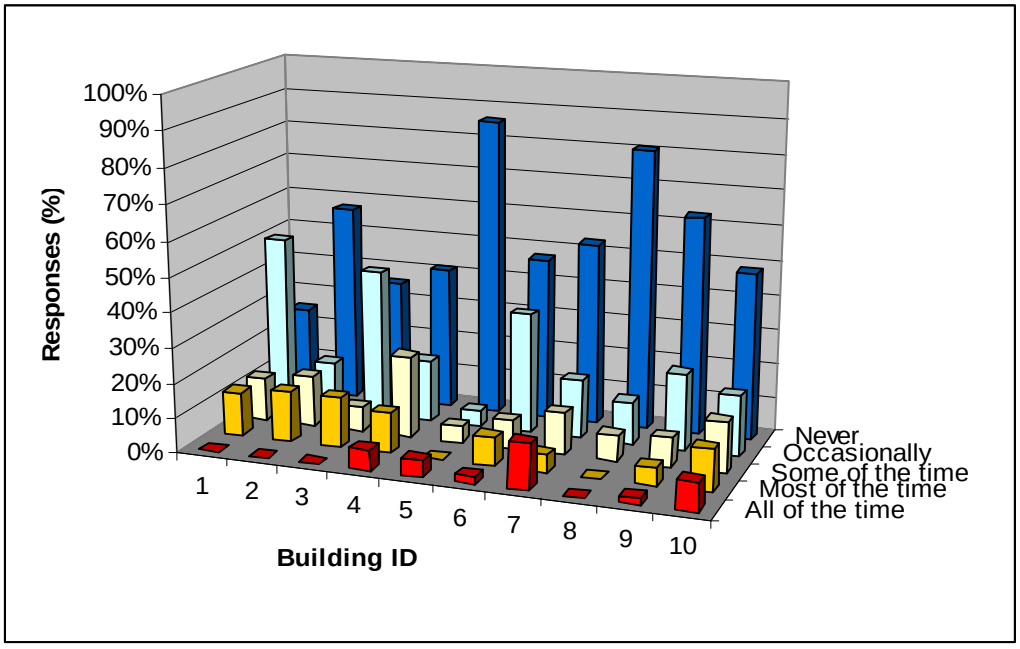


Figure P62. Specific responses on the occupant perception questionnaire when asked how often they could hear sounds of mechanical equipment in the building.

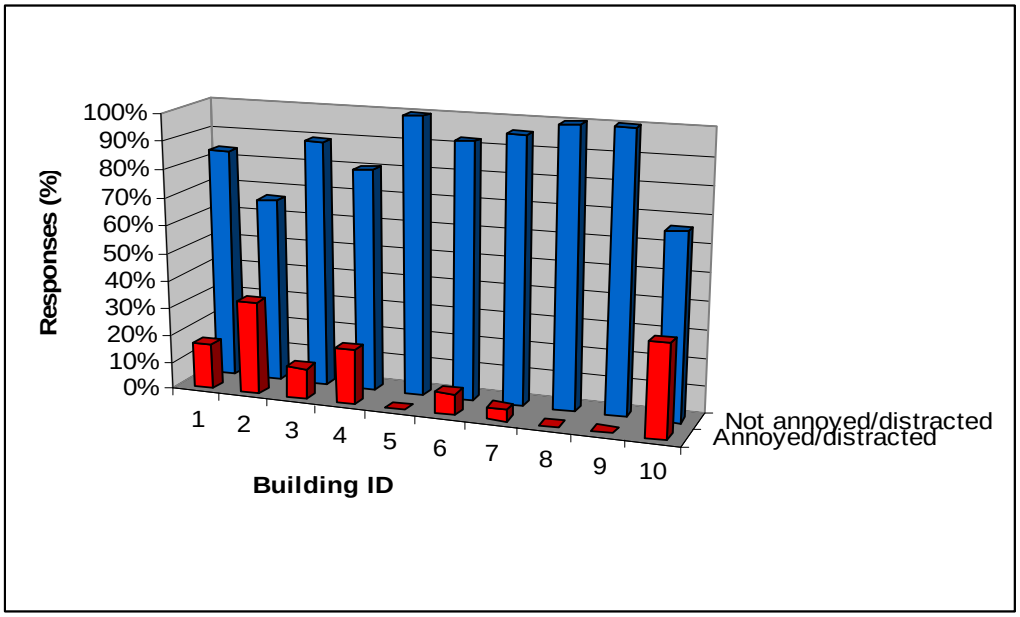


Figure P63. Summary of occupants' responses on the perception questionnaire concerning annoyance/distraction due to hearing of mechanical sounds in the building.

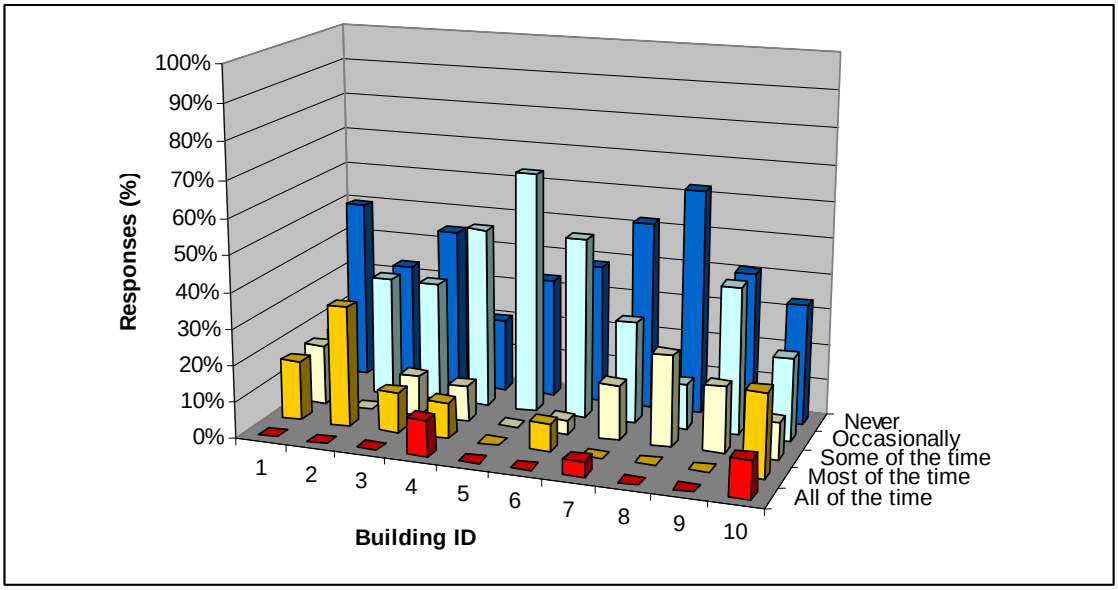


Figure P64. Specific responses on the occupant perception questionnaire when asked how often they were annoyed/distracted due to hearing of mechanical sounds in the building.

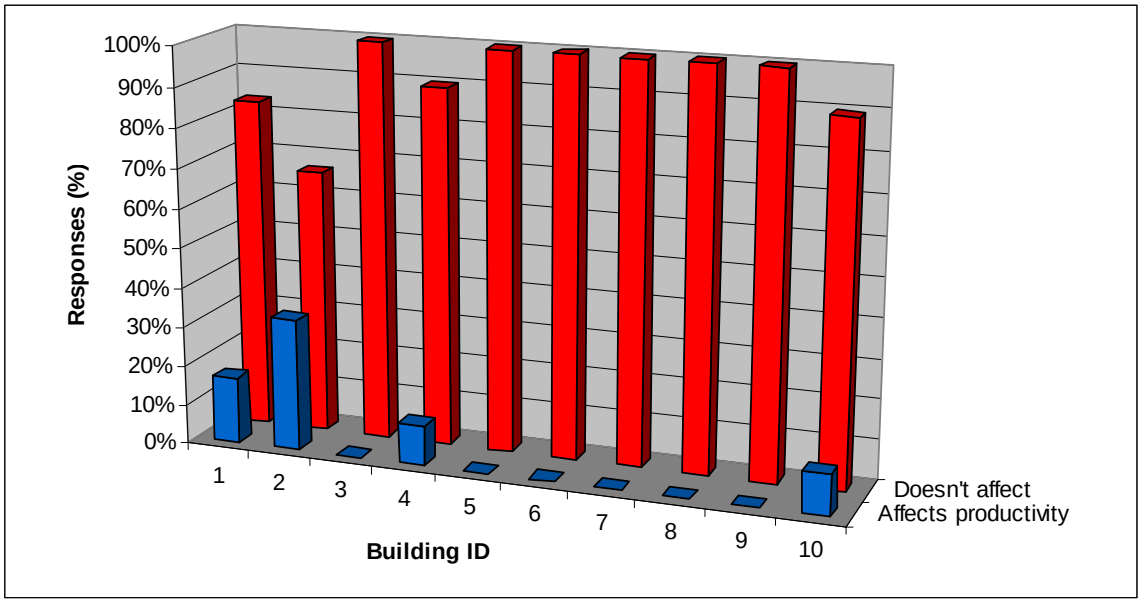


Figure P65. Summary of occupants' responses on the perception questionnaire concerning hearing of mechanical sounds in the building affecting their productivity.

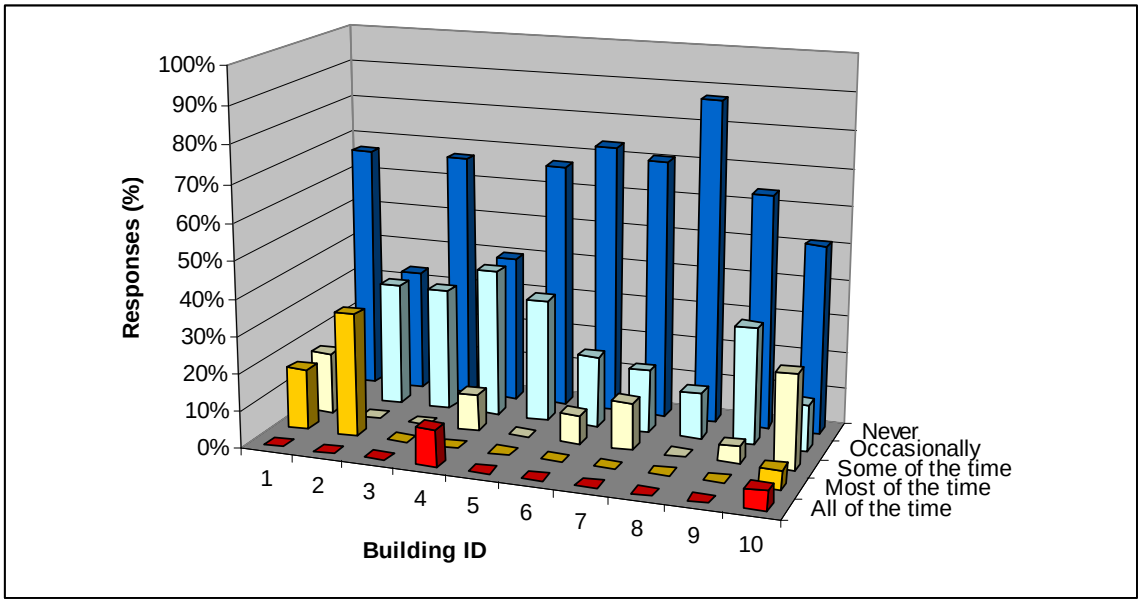


Figure P66. Specific responses on the occupant perception questionnaire when asked how often hearing of mechanical sounds in the building affects their productivity.

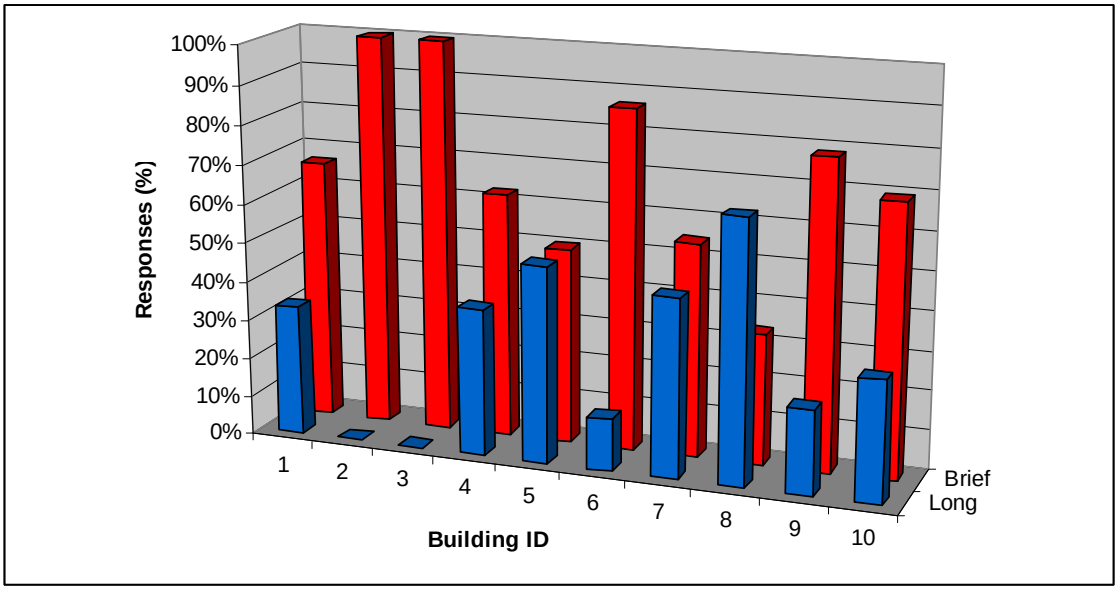


Figure P67. Summary of occupants' responses on the perception questionnaire concerning how quickly (brief of long period) annoyance/distraction occurs after hearing of mechanical sounds in the building.

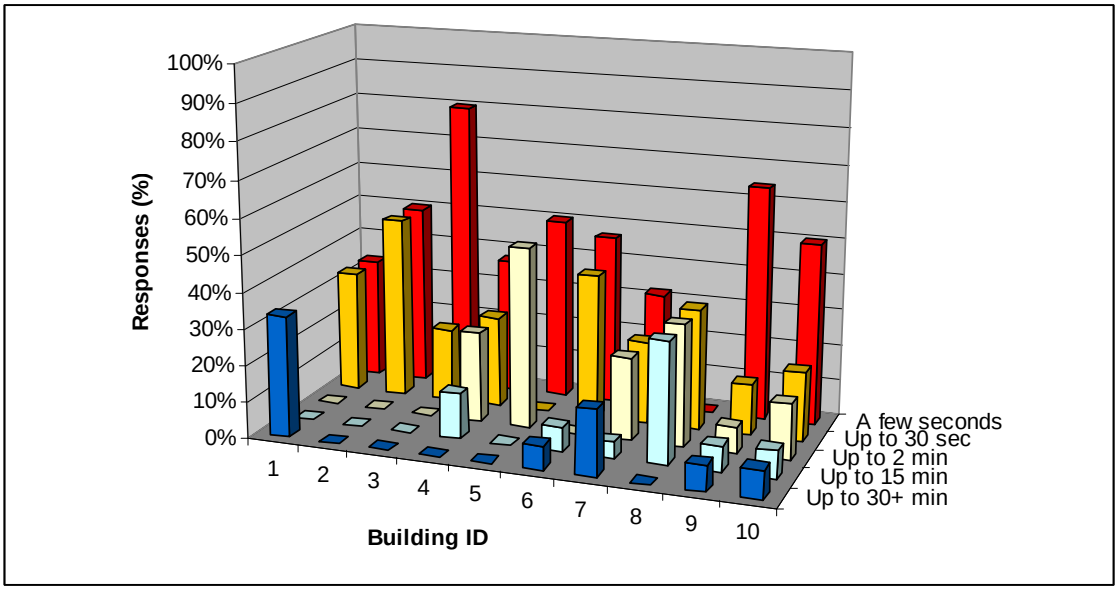


Figure P68. Specific responses on the occupant perception questionnaire when asked how quickly annoyance/distraction occurs after hearing of mechanical sounds in the building.

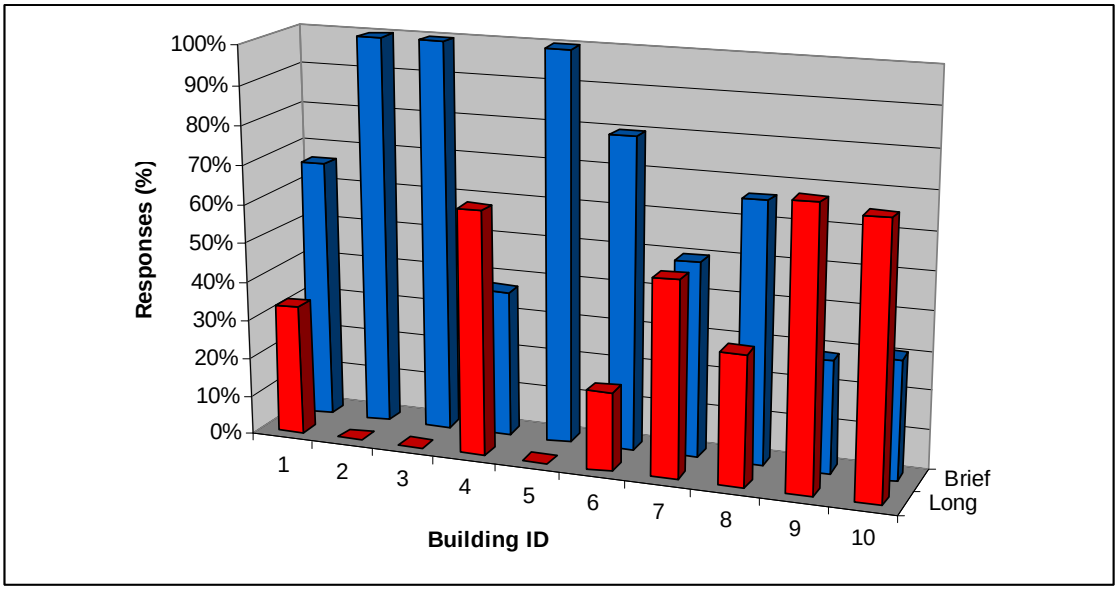


Figure P69. Summary of occupants' responses on the perception questionnaire concerning how long (brief of long period) annoyance/distraction lasts after hearing of mechanical sounds in the building.

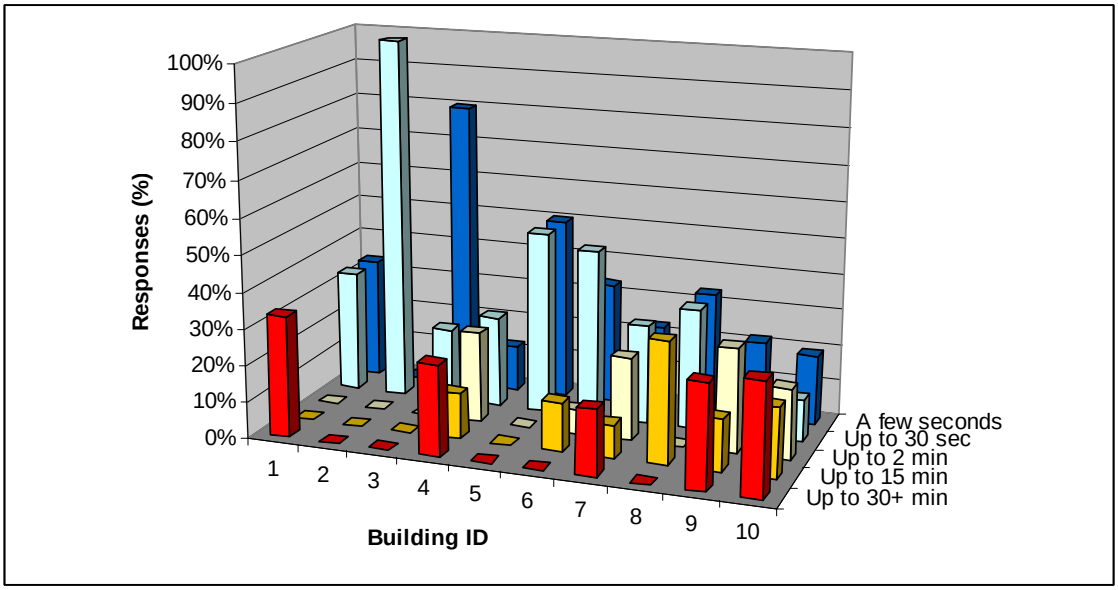


Figure P70. Specific responses on the occupant perception questionnaire when asked how long annoyance/distraction lasts after hearing of mechanical sounds in the building.

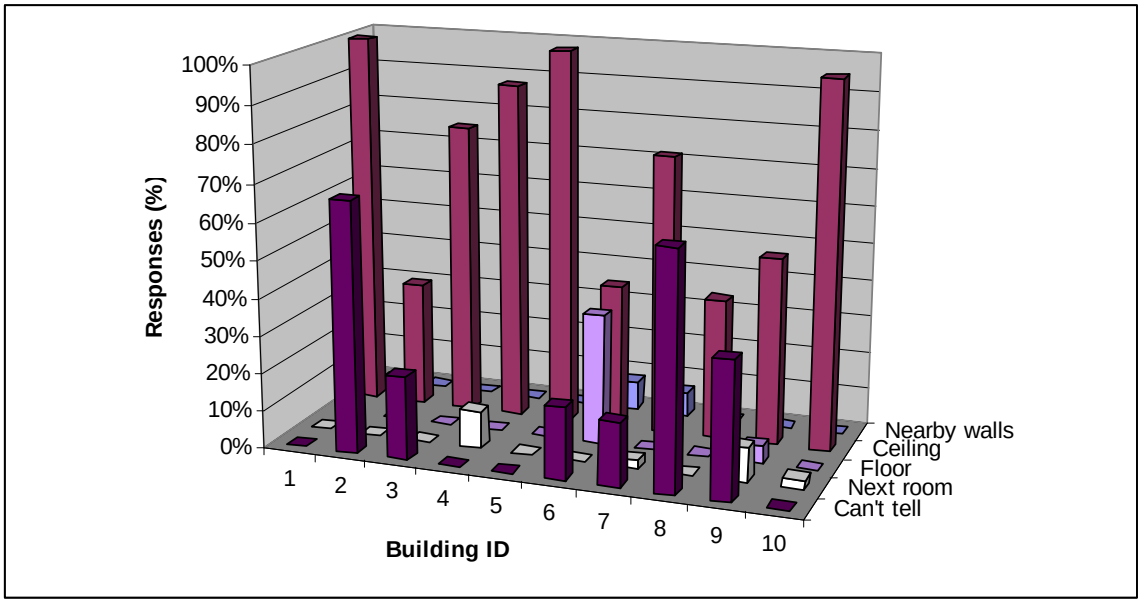


Figure P71. Specific responses on the occupant perception questionnaire when asked the location of hearing sounds from mechanical equipment in the building.

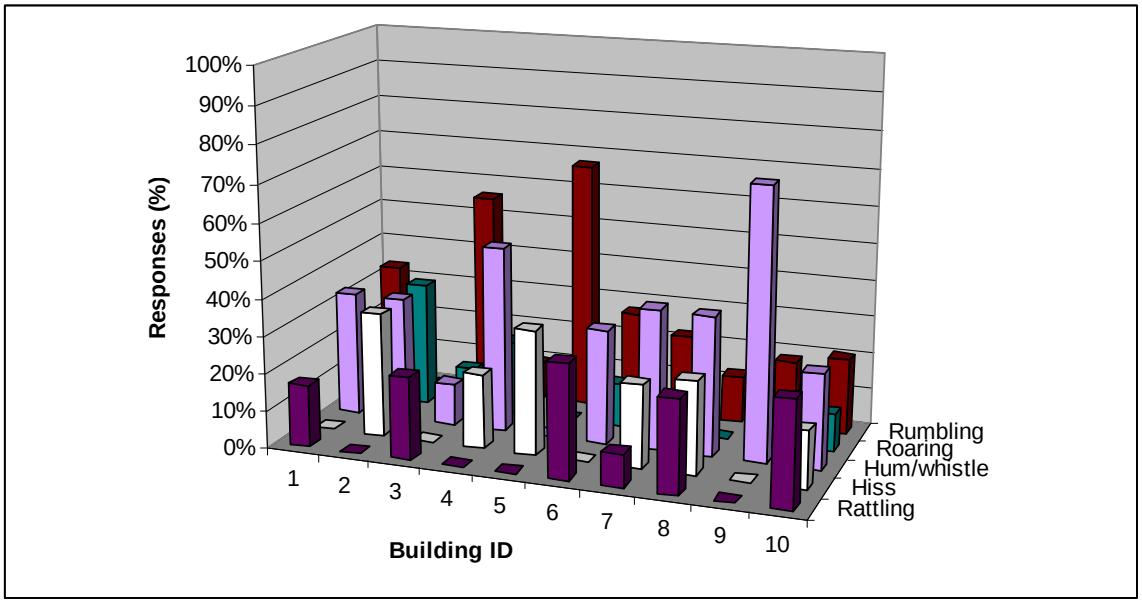


Figure P72. Specific responses on the occupant perception questionnaire when asked what the sounds were from the mechanical equipment in the building.

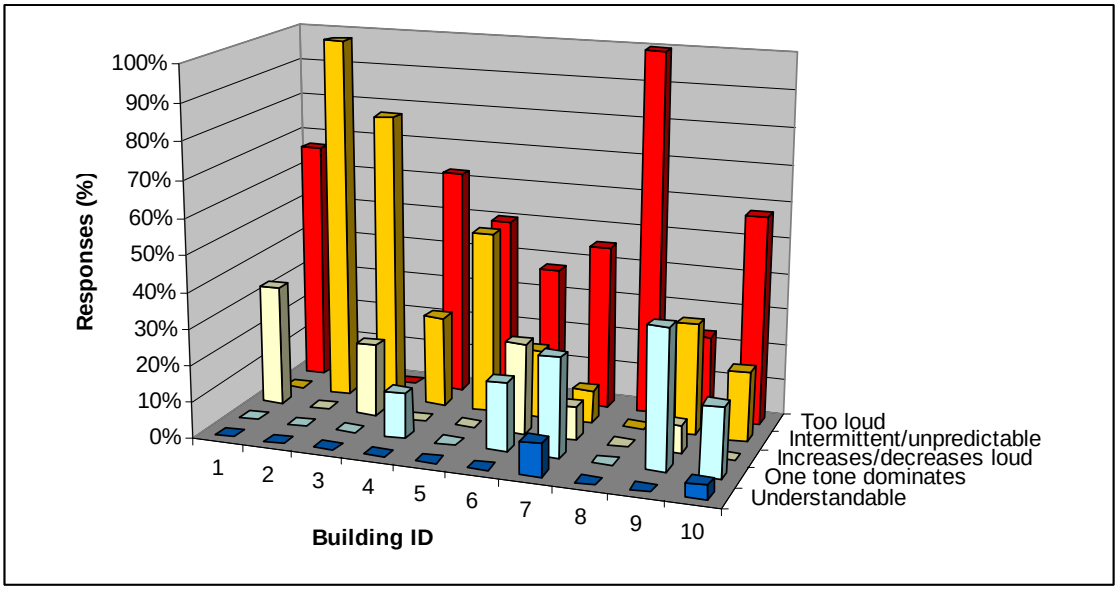


Figure P73. Specific responses on the occupant perception questionnaire when asked the cause of the distraction from hearing of sounds from mechanical equipment in the building.

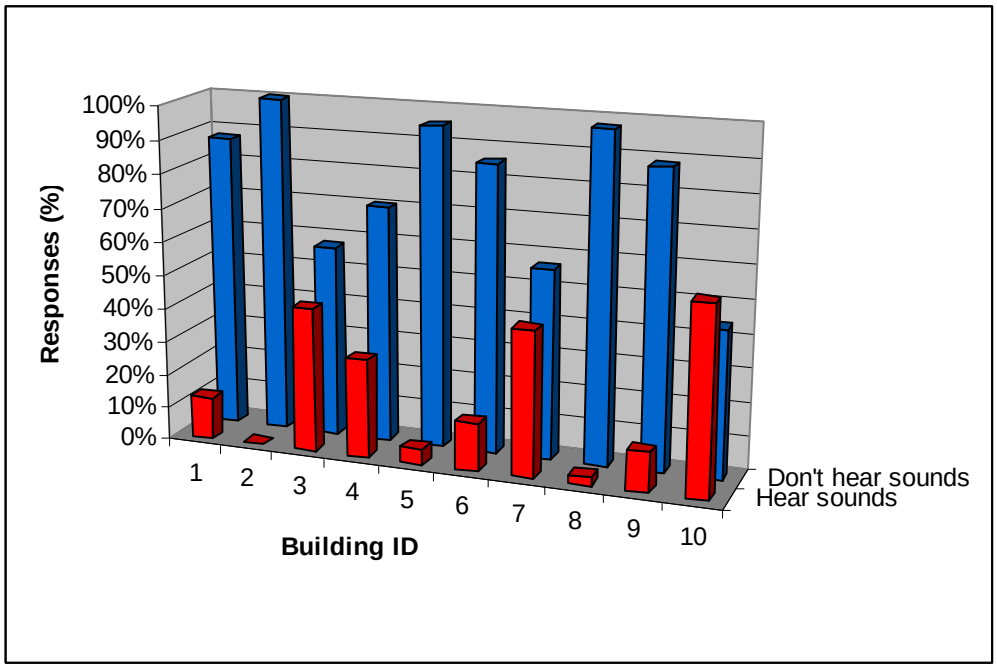


Figure P74. Summary of occupants' responses on the perception questionnaire concerning the hearing of sounds from the air conditioning system the building.

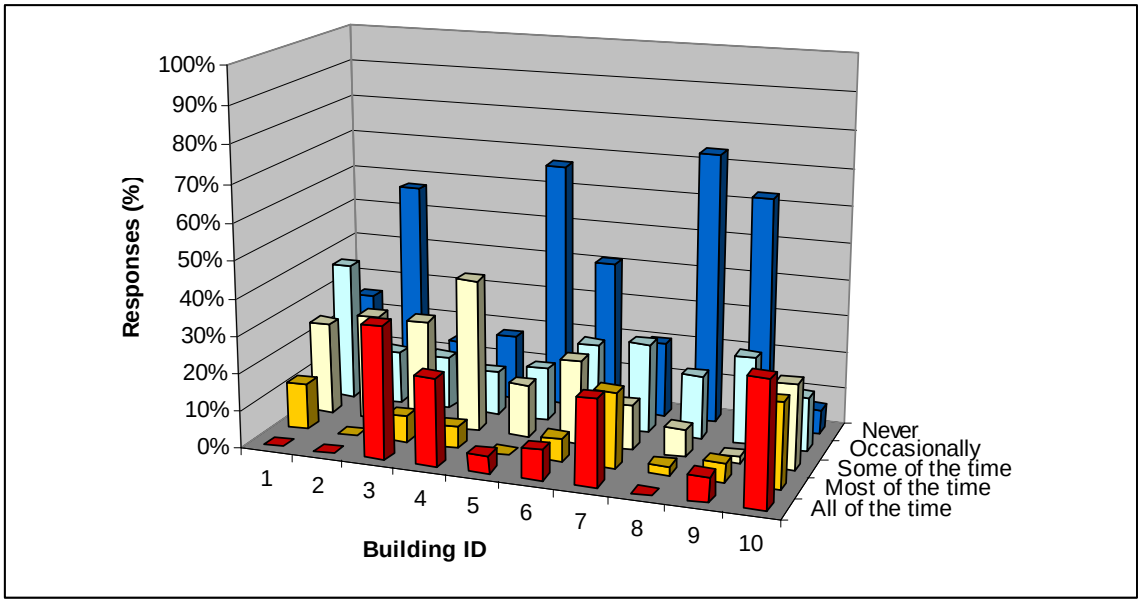


Figure P75. Specific responses on the occupant perception questionnaire when asked how often they could hear sounds from the air conditioning system the building.

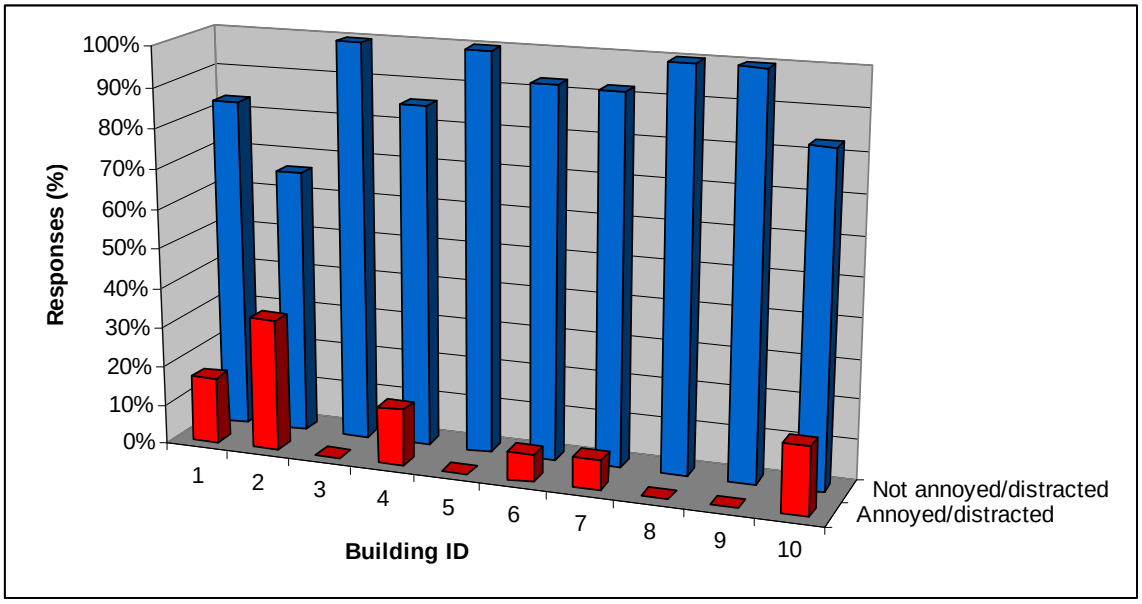


Figure P76. Summary of occupants' responses on the perception questionnaire concerning annoyance/distraction from hearing sounds from the air conditioning system in the building.

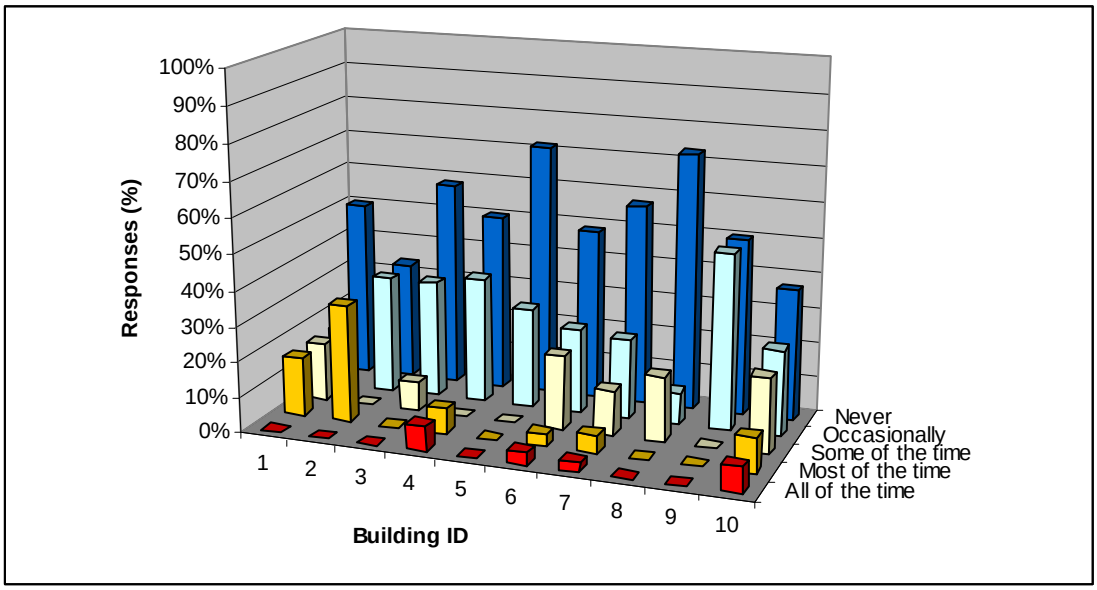


Figure P77. Specific responses on the occupant perception questionnaire when asked how often the hearing of sounds from the air conditioning system in the building is annoying/distracting.

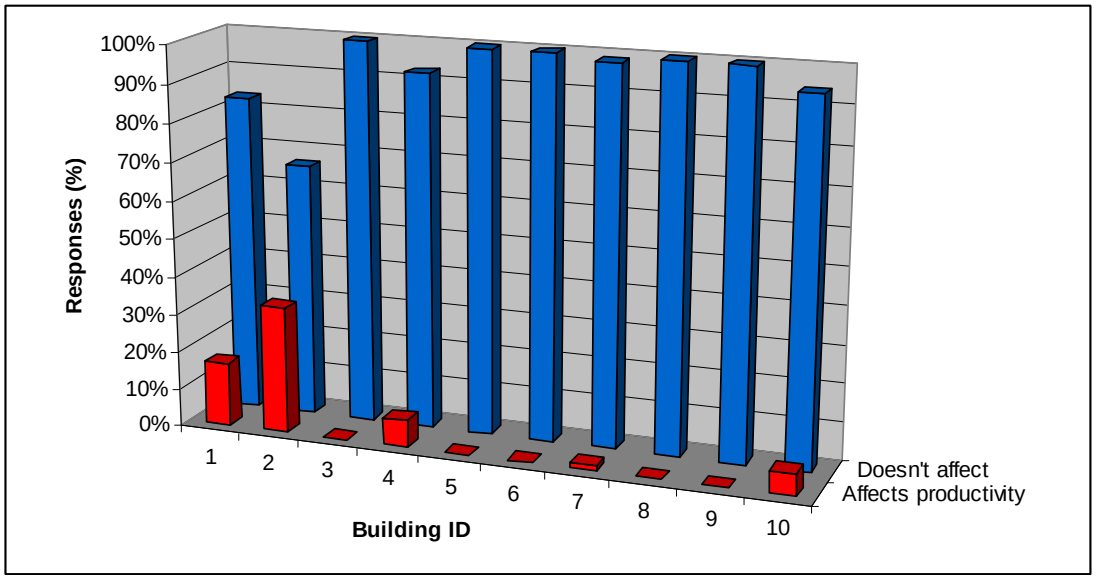


Figure P78. Summary of occupants' responses on the perception questionnaire concerning hearing sounds from the air conditioning system in the building affecting productivity.

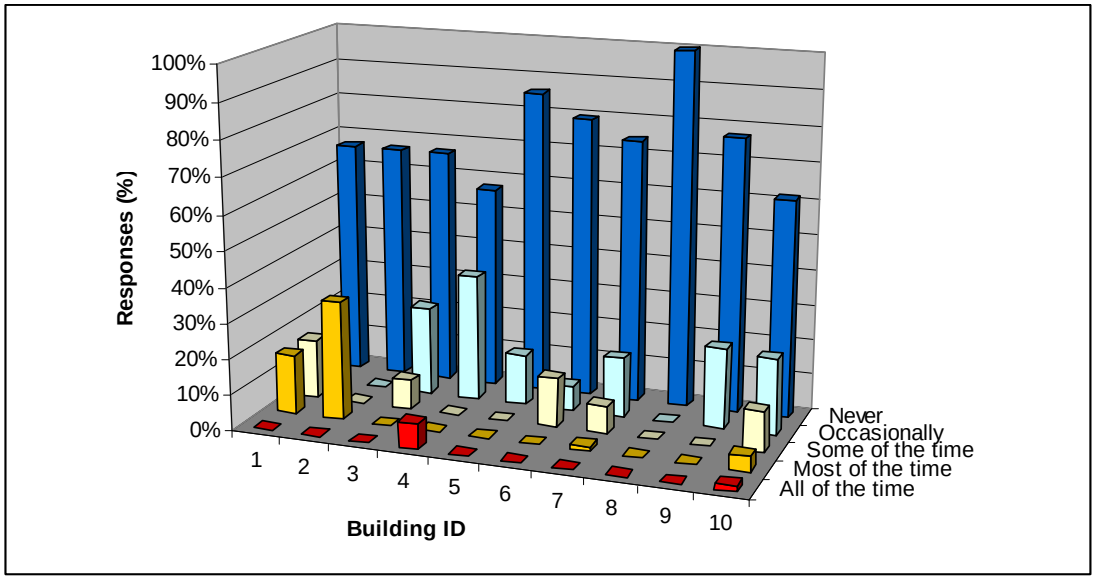


Figure P79. Specific responses on the occupant perception questionnaire when asked how often hearing sounds from the air conditioning system in the building affects productivity.

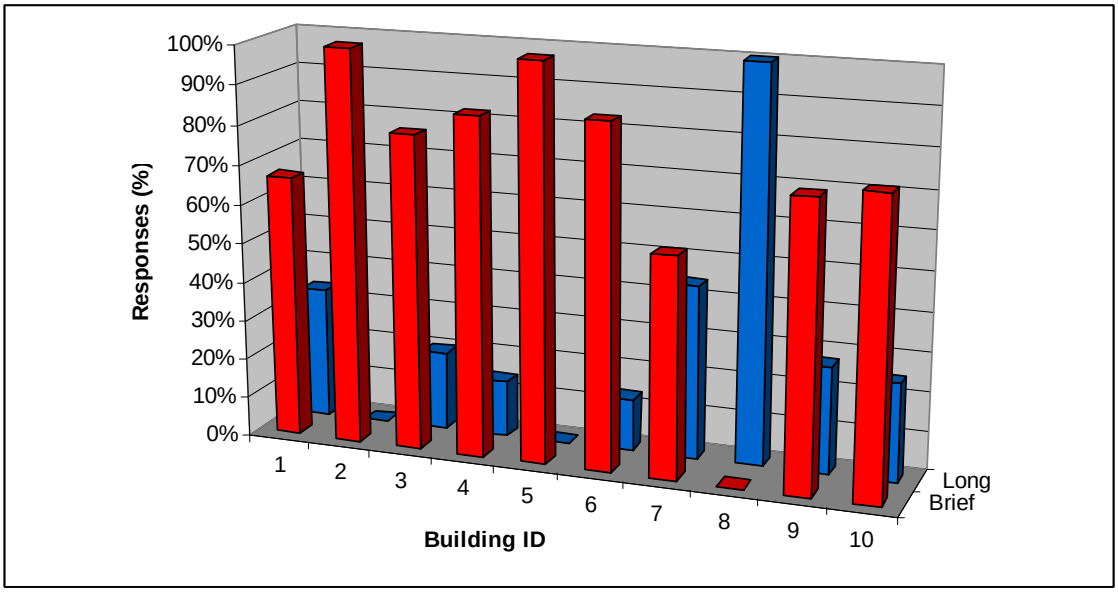


Figure P80. Summary of occupants' responses on the perception questionnaire concerning how quickly (brief or long period) hearing sounds from the air conditioning system is disturbing.

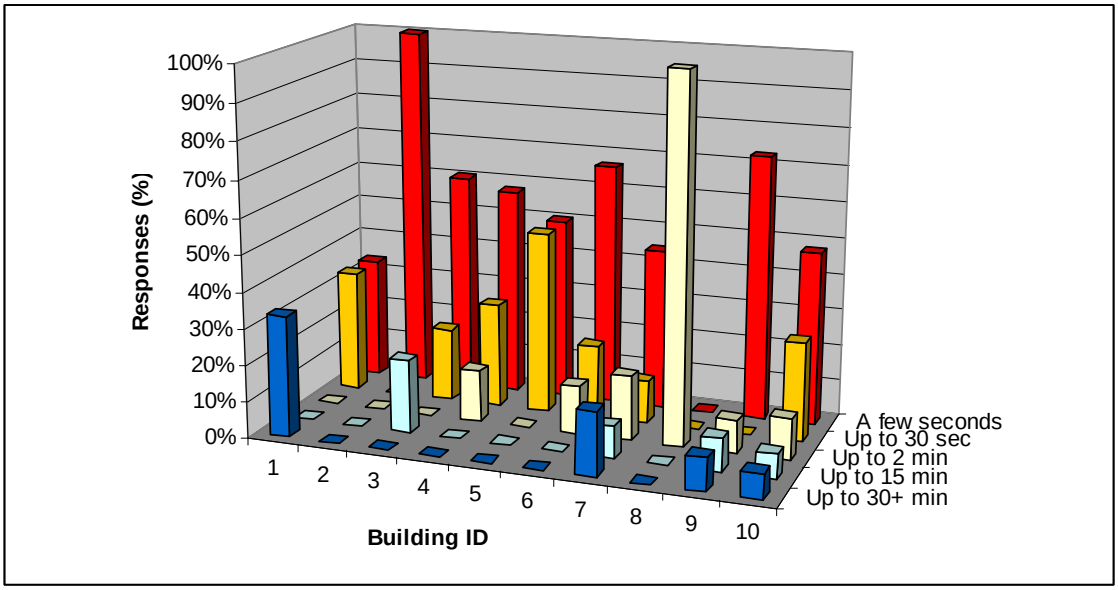


Figure P81. Specific responses on the occupant perception questionnaire when asked how quickly hearing sounds from the air conditioning system in the building is disturbing.

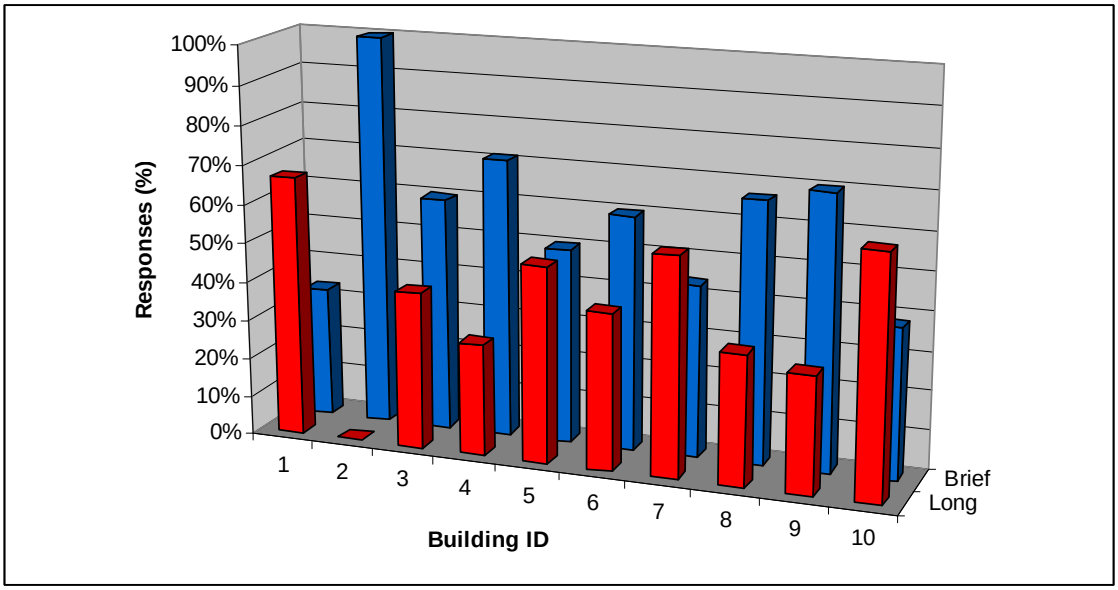


Figure P82. Summary of occupants' responses on the perception questionnaire concerning the length (brief or long period) that the disturbance lasted following hearing sounds from the air conditioning system in the building.

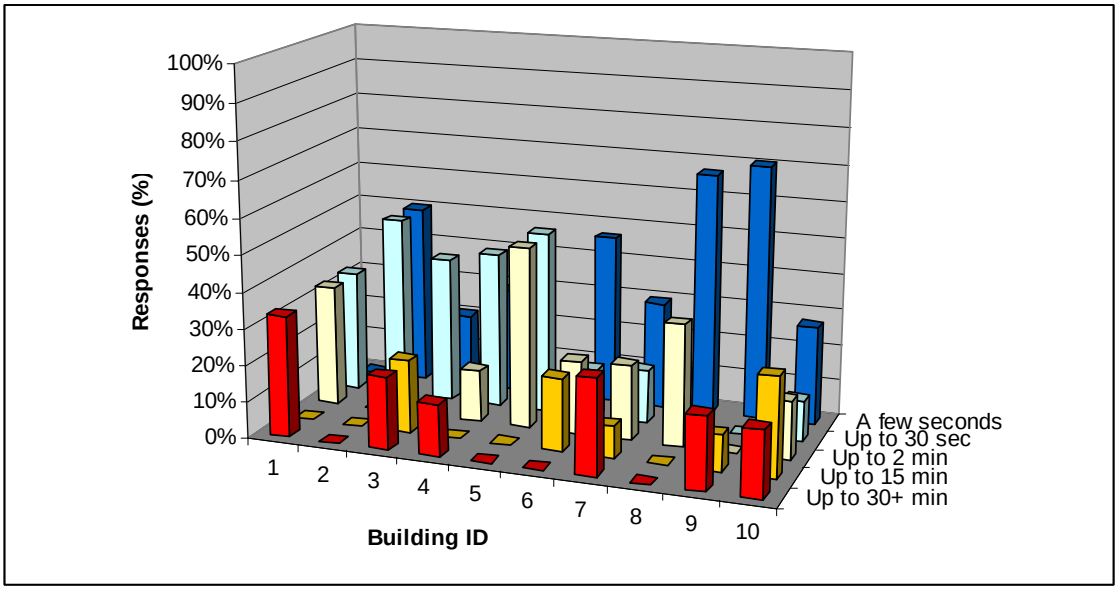


Figure P83. Specific responses on the occupant perception questionnaire when asked how long the disturbance lasted following hearing sounds from the air conditioning system in the building.

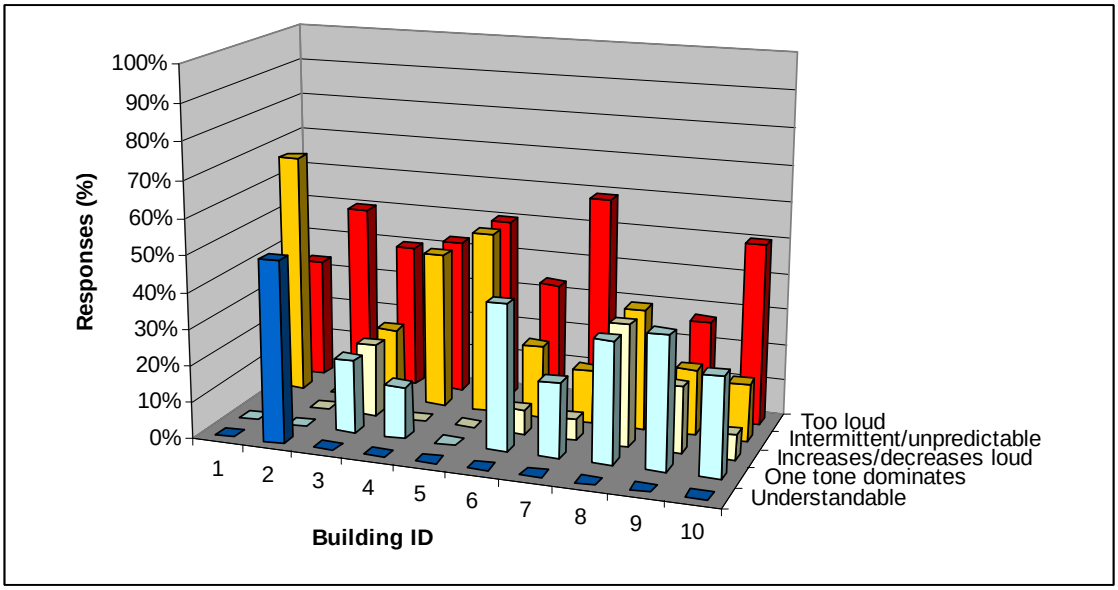


Figure P84. Specific responses on the occupant perception questionnaire when asked the cause of the disturbance from hearing sounds from the air conditioning system in the building.

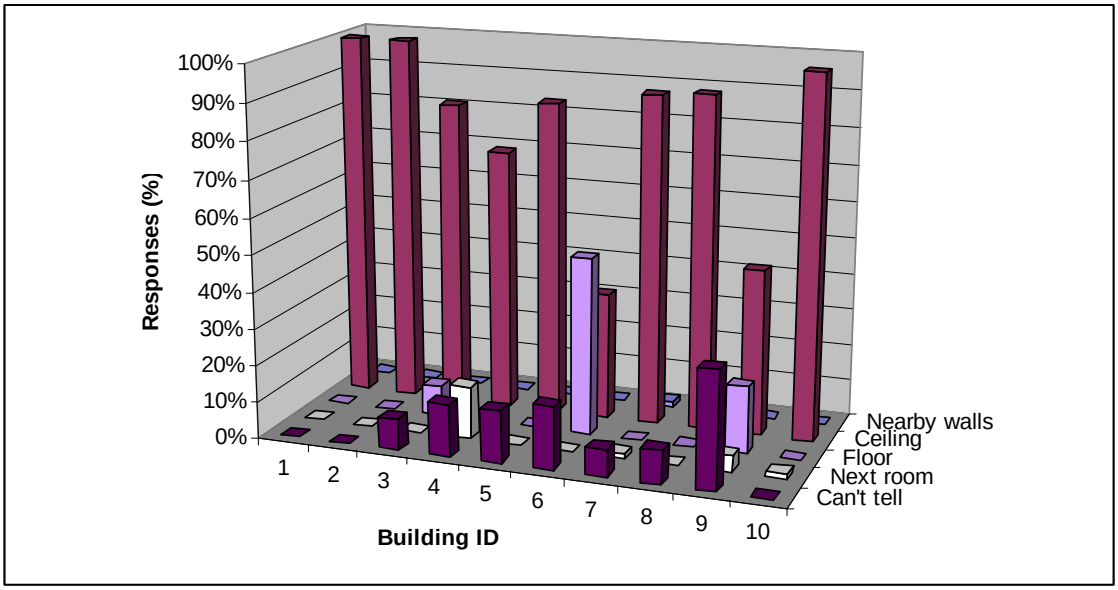


Figure P85. Specific responses on the occupant perception questionnaire when asked the location of hearing sounds from the air conditioning system in the building.

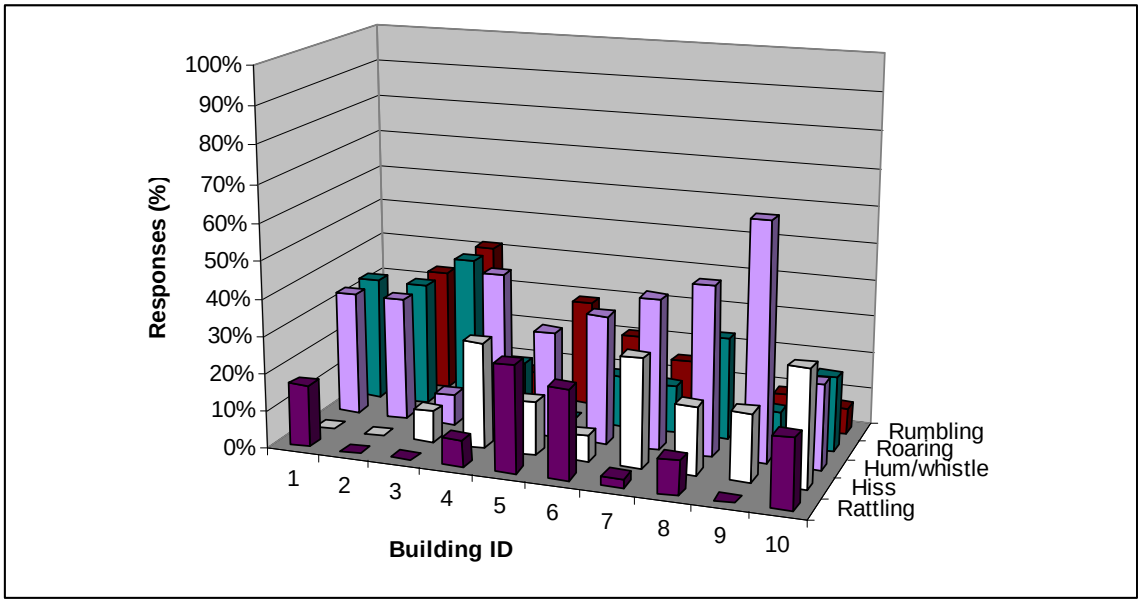


Figure P86. Specific responses on the occupant perception questionnaire when asked what the sounds were from the air conditioning system in the building.

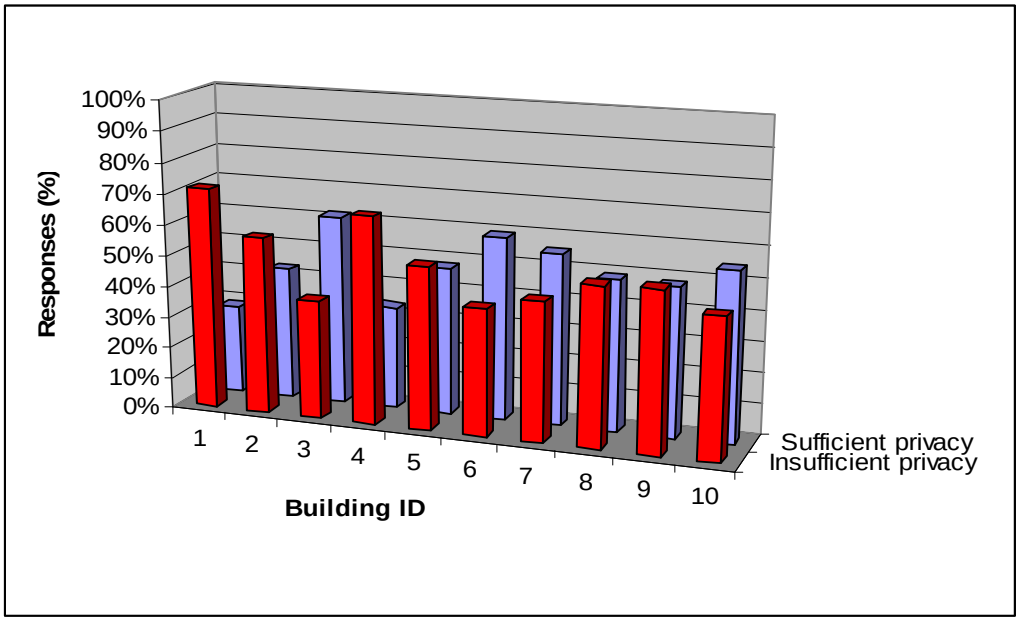


Figure P87. Summary of occupants' responses on the perception questionnaire concerning privacy to have a conversation in their work area.

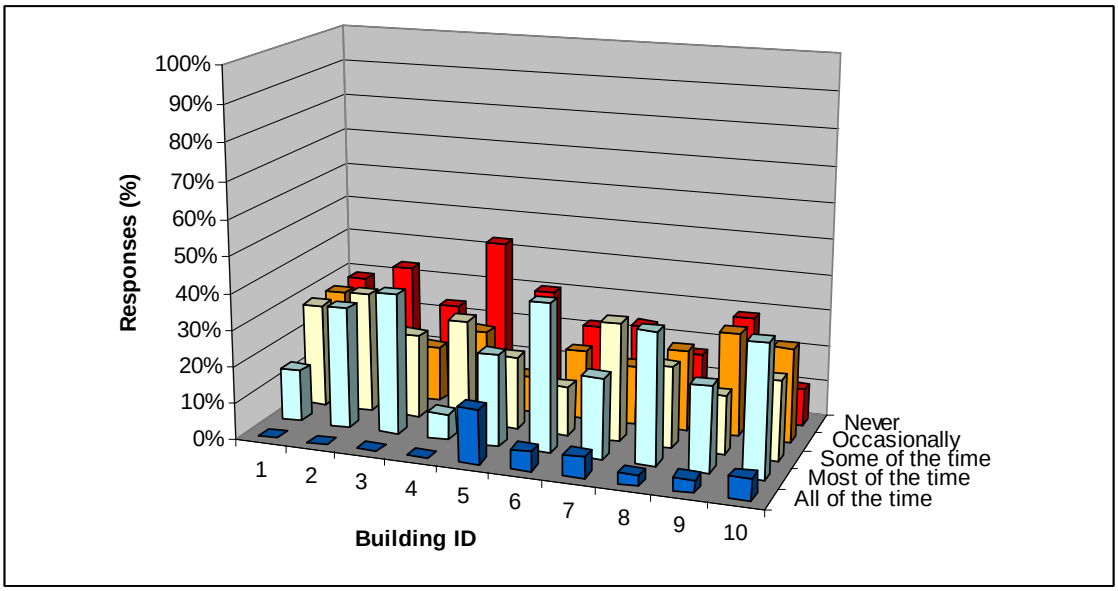


Figure P88. Specific responses on the occupant perception questionnaire when asked about how often there was privacy to have a conversation in their work area.

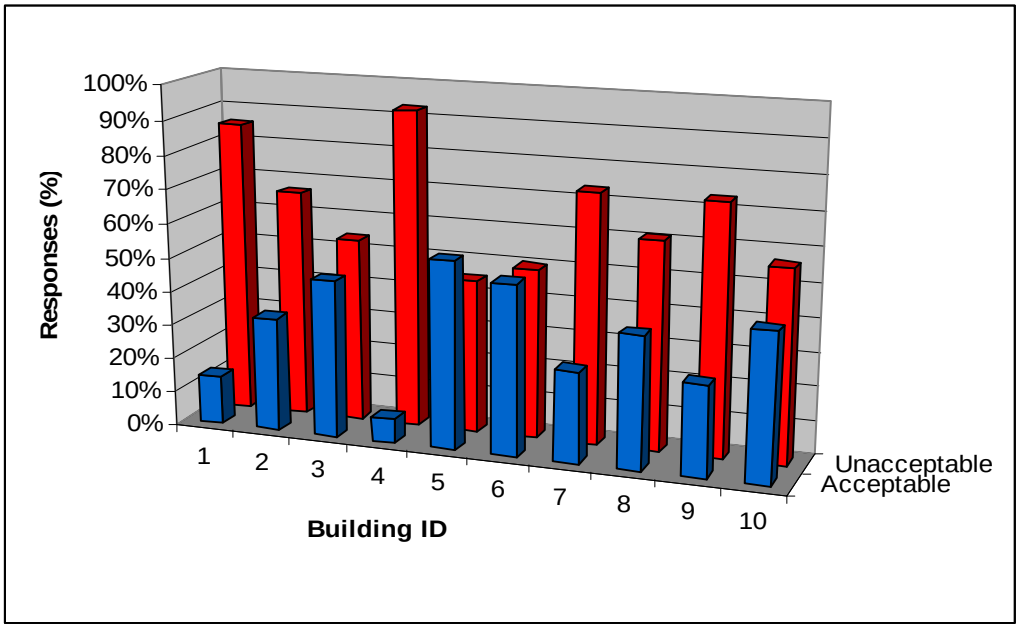


Figure P89. Summary of occupants' responses on the perception questionnaire concerning privacy to have a telephone conversation in their work area.

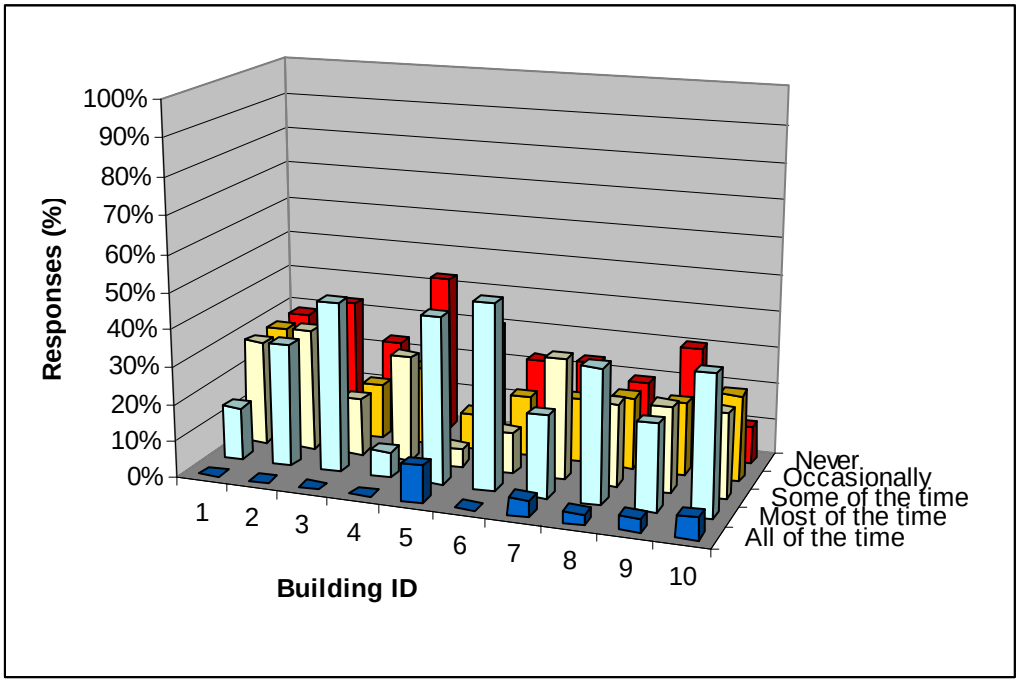


Figure P90. Specific responses on the occupant perception questionnaire when asked how often there was acceptable privacy to have a telephone conversation in their work area.

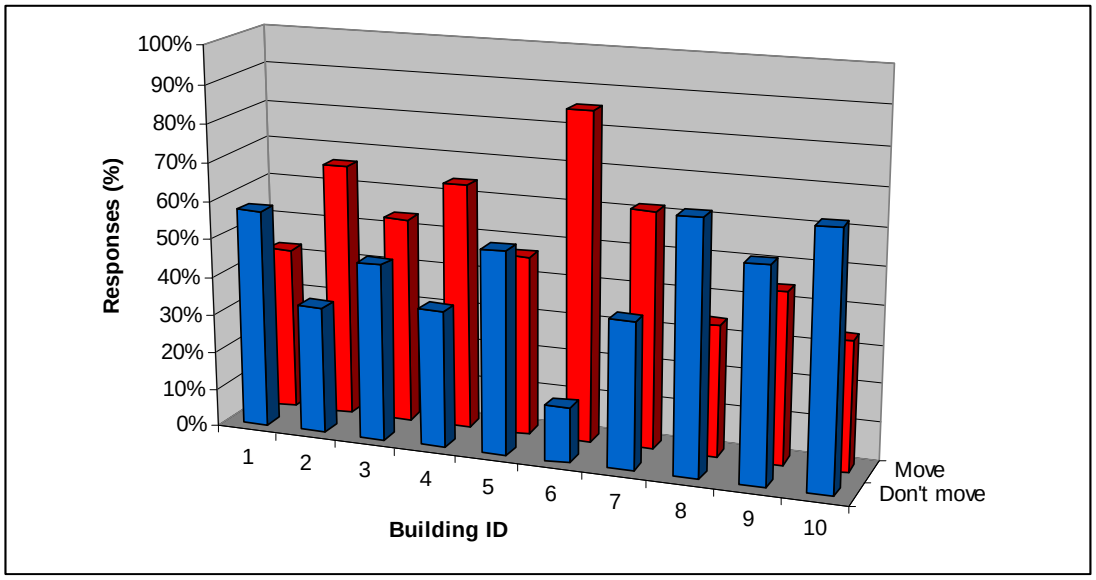


Figure P91. Summary of occupants' responses on the perception questionnaire concerning moving to another location have privacy for a conversation.

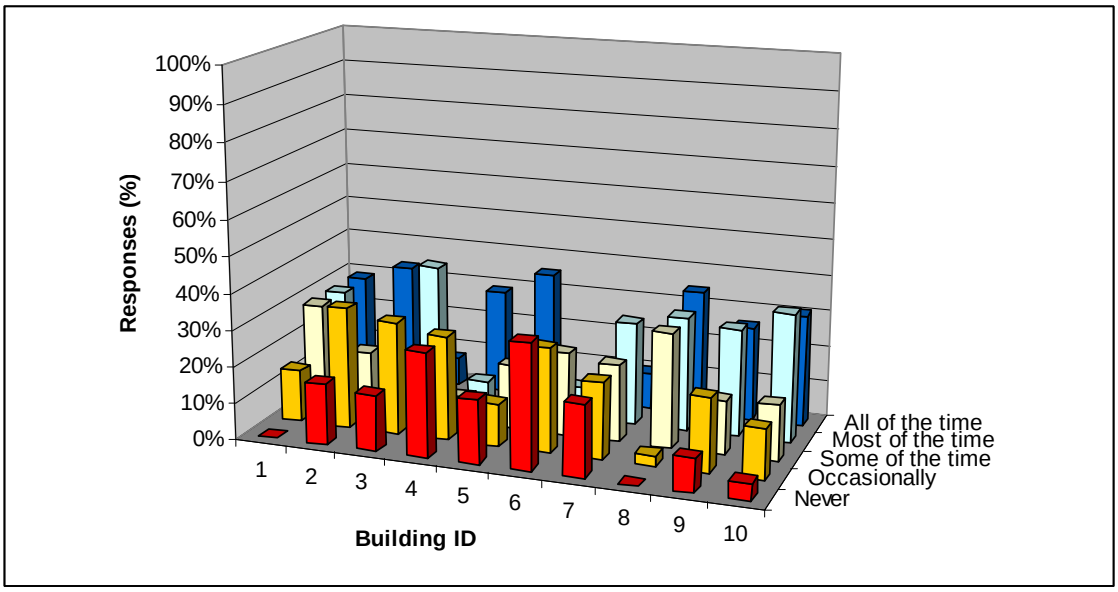


Figure P92. Specific responses on the occupant perception questionnaire when asked how often they moved to another location to have privacy for a conversation.

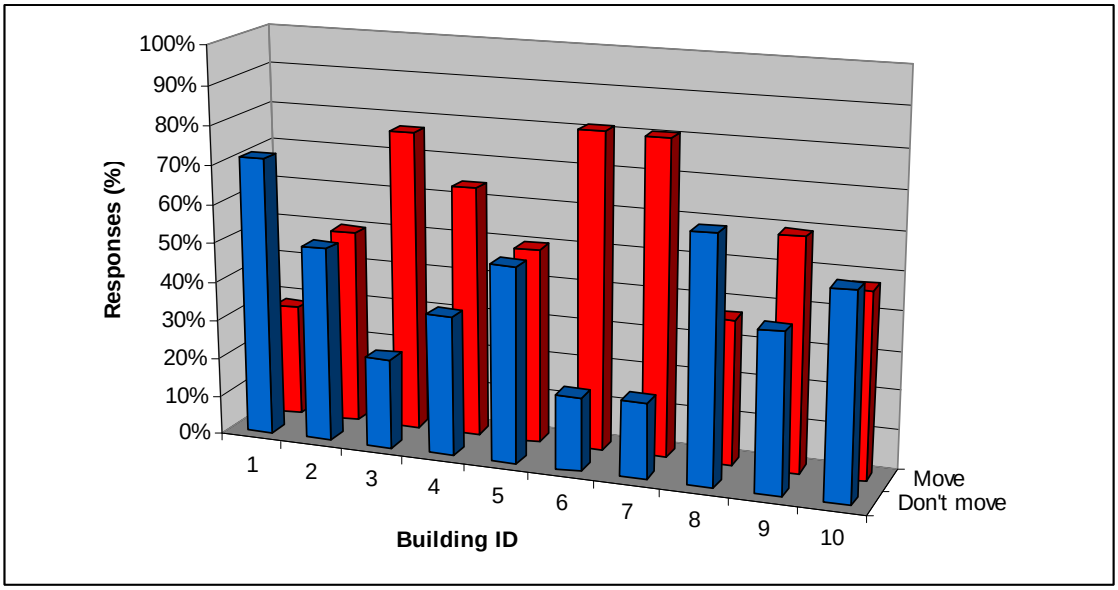


Figure P93. Summary of occupants' responses on the perception questionnaire concerning moving to another location have a telephone conversation.

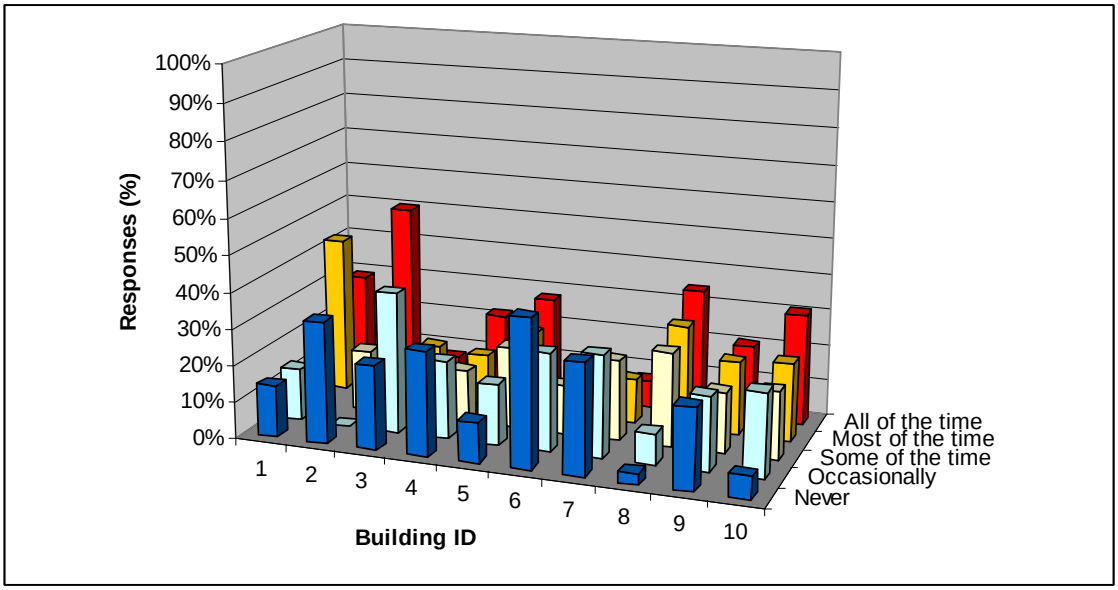


Figure P94. Specific responses on the occupant perception questionnaire when asked how often they moved to another location for telephone privacy.

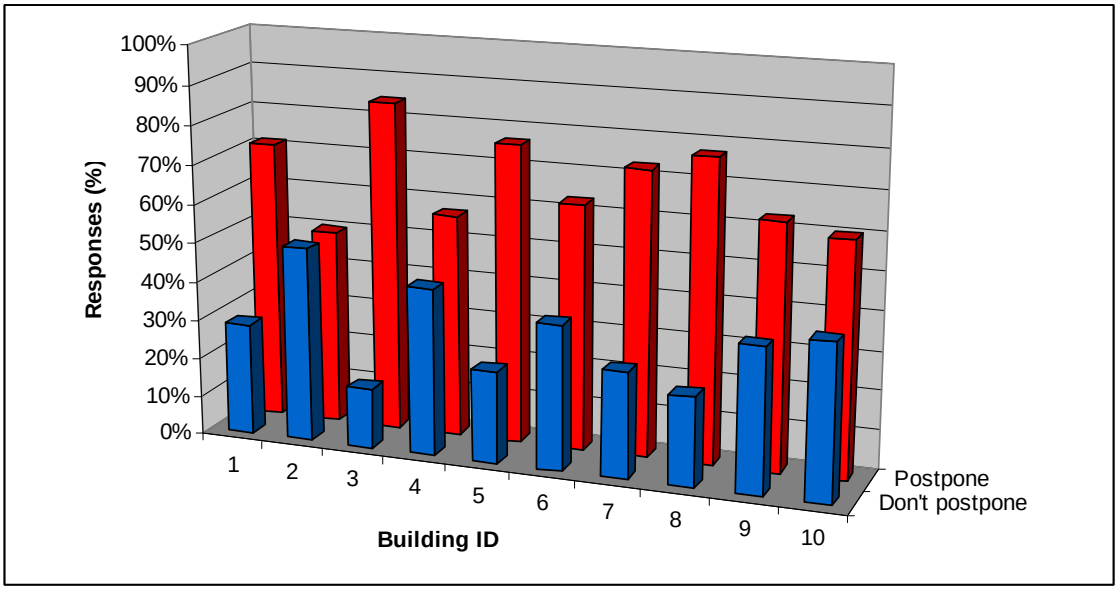


Figure P95. Summary of occupants' responses on the perception questionnaire concerning postponing a conversation until later due to lack of privacy in their work area.

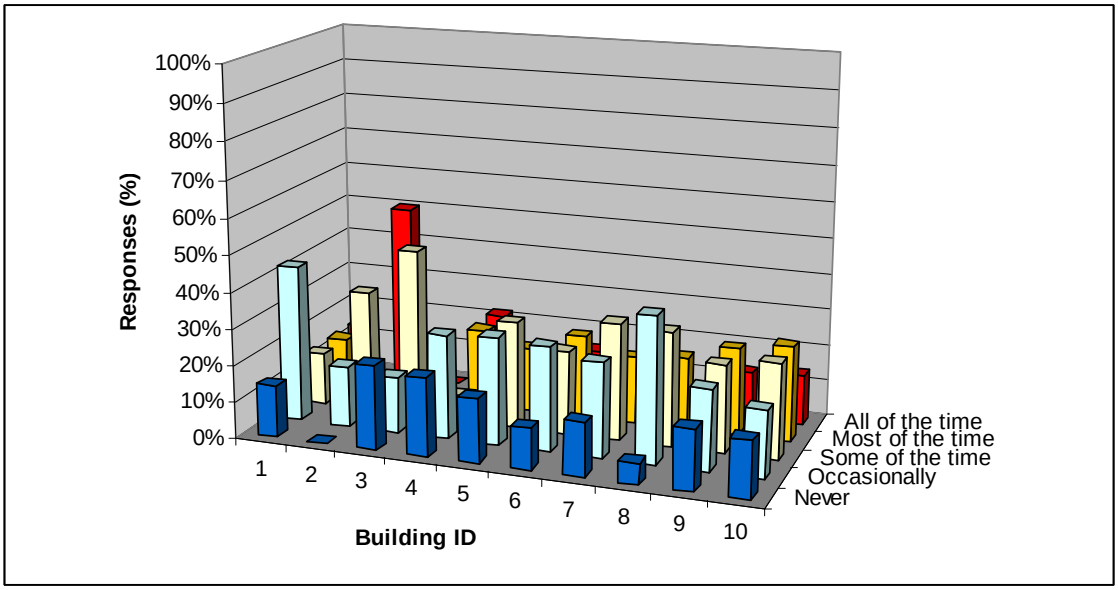


Figure P96. Specific responses on the occupant perception questionnaire when asked how often they postponed a conversation until later due to lack of privacy in their work area.

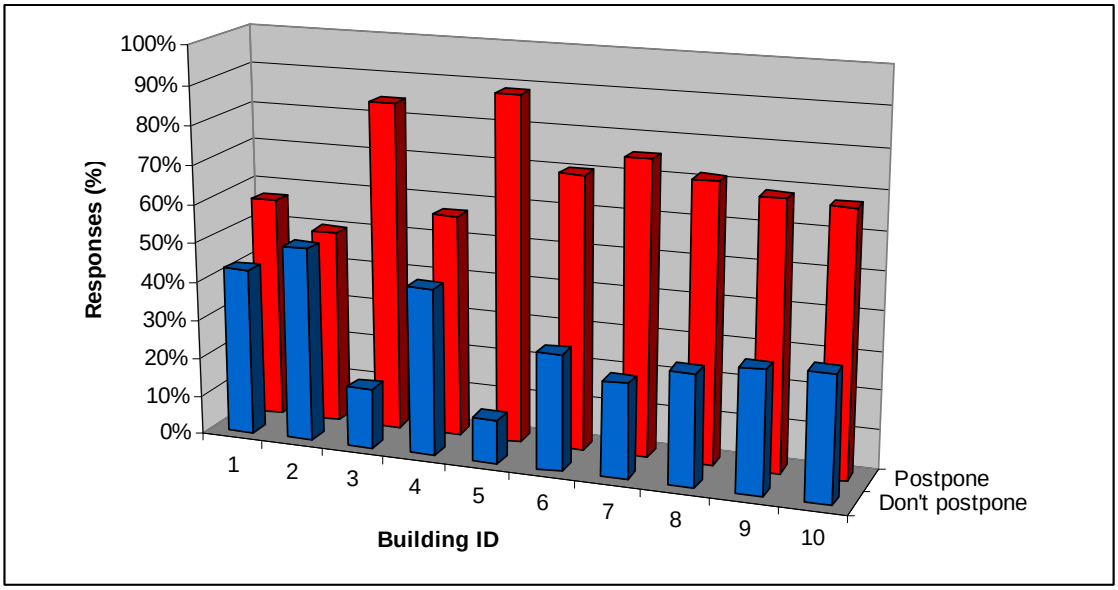


Figure P97. Summary of occupants' responses on the perception questionnaire concerning postponing a telephone conversation until later due to lack of privacy in their work area.

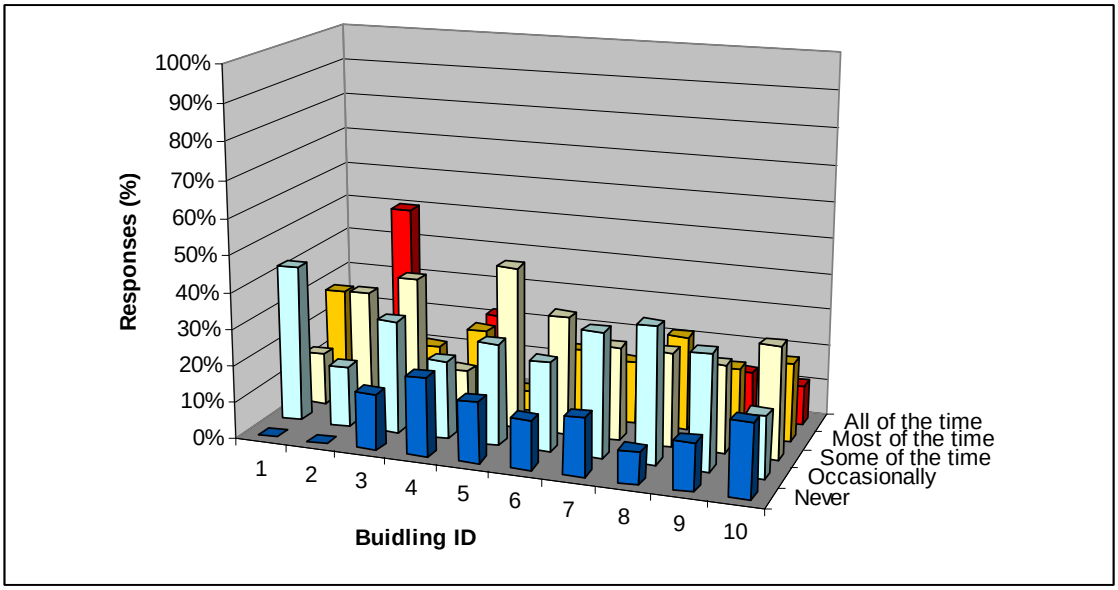


Figure P98. Specific responses on the occupant perception questionnaire when asked how often they postponed a telephone conversation until later due to lack of privacy in their work area.

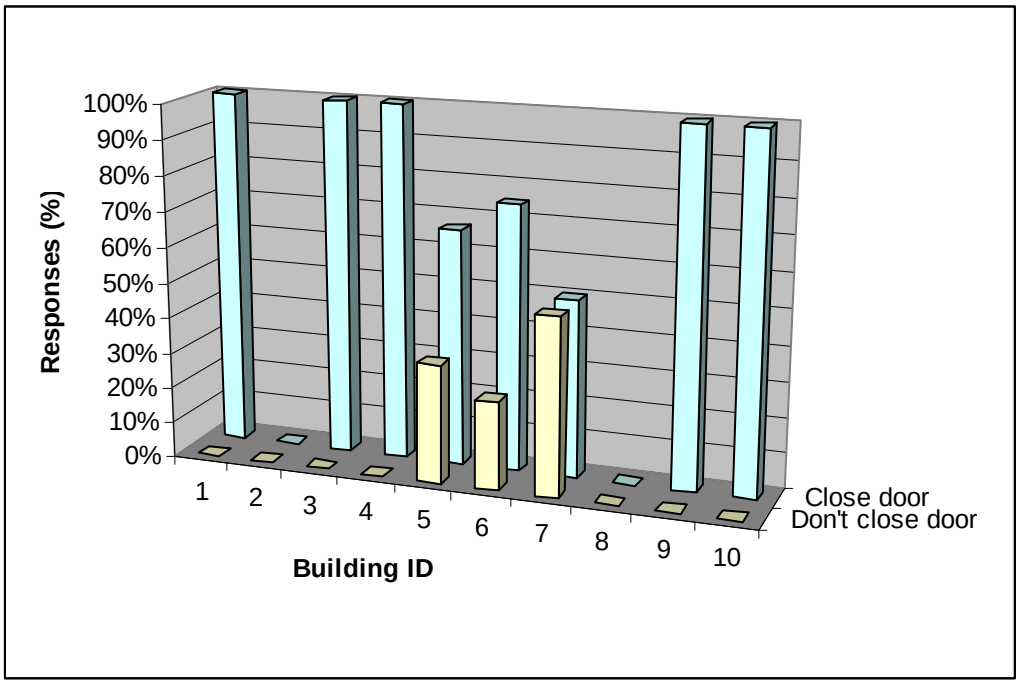


Figure P99. Summary of occupants' responses on the perception questionnaire concerning closing of a door to gain privacy in their work area.

APPENDIX Q- SOUND LEVEL DATA

Summary of Calculated Values.

Q1. dBA Bumps

These data are used to describe sound level measurements for various frequencies that exceed the levels of their immediate neighbors by the variances shown below. Items that equal or exceed the variance are identified with the value of 1 otherwise they contain the value of zero.

Description	Field Name	Columns
1/1 octave band, 4dB variance	**DBA11_63_6** through **DB11_4000_4**	7
1/1 octave band, 6dB variance	**DBA11_63_6** through **DB11_4000_6**	7
1/1 octave band, 8dB variance	**DBA11_63_6** through **DB11_4000_8**	7
1/3 octave band, 4dB variance	**DBA13_63_6** through **DB13_8000_4**	22
1/3 octave band, 6dB variance	**DBA13_63_6** through **DB13_8000_6**	22
1/3 octave band, 8dB variance	**DBA13_63_6** through **DB13_8000_8**	22

Q2. dBC

See SPL_C in raw data (Float)

Q3. dBC - dBA

Use SPL_C - SPL_A in raw data (Float)

Q4. NC – Noise Criteria

NC selects the highest measured sound level that fits within a standardized sound level.

NCMax stores the maximum sound level found. (Float)

NCFreq stores the frequency where this sound level was found. (Integer)

Q5. NCB – Balanced Noise Criteria

NCB is one method to determine if rumble and hiss exist in a sound sample.

SIL stores the Sound Interface Level used to select the NCB reference level for rumble (Float)

NCBRumble stores a 1 if rumble is detected otherwise a 0 (Integer)

NCBRefHiss stores the NCB reference level for hiss (Integer)

NCBHiss stores a 1 if hiss is detected otherwise 0 (Integer)

Q6. RC – Room Criteria

RC stores the RC table level that is used for analyzing hiss and rumble (Float)

RCRumble stores a 1 if rumble is detected otherwise a 0 (Integer)

RCHiss stores a 1 if hiss is detected otherwise a 0 (Integer)

Q7. RC Mark II (RCII) Alternate Room criteria

RCII is another derivative that analyzes rumble, hiss and an intermediate quality descriptor named roar.

RCII stores the RC table level that is used for analyzing hiss, rumble and roar (Integer)

DeltaLF stores a cumulative difference between the table and the measured low freq values (Float)

DeltaMF stores a cumulative difference between the table and the measured med freq values (Float)

DeltaHF stores a cumulative difference between the table and the measured high freq values (Float)

RCIIQual stores the indicator for the highest Delta, 0=none, 1=LF, 2=MF, 3=HF, whenever DeltaMax is greater than 5 (Integer)

DeltaMax (QAI) stores the largest difference between any pair of Deltas above (Float)

Q8. Cumulative Probability Levels (CPL)

CPL defines a level for a measurement where a specified percentage of the samples fall at or below the indicated percentage. The following table shows how to construct the 8 field names for the each of the four measurements, dBA, dBC, dBC_dBA, NCMax, RC and SIL:

Prefix	Suffixes					
L_99_	dBA	dBC	dBC_dBA	NCMax	RC	SIL
L_95_	dBA	dBC	dBC_dBA	NCMax	RC	SIL
L_90_	dBA	dBC	dBC_dBA	NCMax	RC	SIL
L_80_	dBA	dBC	dBC_dBA	NCMax	RC	SIL
L_50_	dBA	dBC	dBC_dBA	NCMax	RC	SIL
L_33_	dBA	dBC	dBC_dBA	NCMax	RC	SIL
L_10_	dBA	dBC	dBC_dBA	NCMax	RC	SIL
L_05_	dBA	dBC	dBC_dBA	NCMax	RC	SIL

dBA is raw SPL_A data taken form the samples (Float)

dBA is raw SPL_C data taken form the samples (Float)

dBA_dBA is raw SPL_C minus the raw SLP_A data taken form the samples (Float)

NCMax is the calculated sound level from the NC sections above (Float)

RC is the value stored in the RC sections above (Float)

SIL is the value stored in the NCB sections above (Float)

Q9. Covariance In Sound Measurements Using Analysis Of Covariance (ANCOVA)

Table Q1. Variance in sound interference level (SIL) measurements.

Factor	Sound Measure	Percentage
Building	L_95_SIL	10%
Zone	L_95_SIL	79%
Sampling Date	L_95_SIL	10%
Residual	L_95_SIL	0%
Building	L_90_SIL	15%
Zone	L_90_SIL	71%
Sampling Date	L_90_SIL	15%
Residual	L_90_SIL	0%
Building	L_80_SIL	16%
Zone	L_80_SIL	67%
Sampling Date	L_80_SIL	16%
Residual	L_80_SIL	0%
Building	L_50_SIL	19%
Zone	L_50_SIL	62%
Sampling Date	L_50_SIL	19%
Residual	L_50_SIL	0%
Building	L_10_SIL	27%
Zone	L_10_SIL	46%
Sampling Date	L_10_SIL	27%
Residual	L_10_SIL	0%

Table Q2. Variance in sound dBA measurements.

Factor	Sound Measure	Percentage
Building	L_99_dBA	11%
Zone	L_99_dBA	78%
Sampling Date	L_99_dBA	11%
Residual	L_99_dBA	0%
Building	L_95_dBA	11%
Zone	L_95_dBA	79%
Sampling Date	L_95_dBA	11%
Residual	L_95_dBA	0%
Building	L_90_dBA	14%
Zone	L_90_dBA	72%
Sampling Date	L_90_dBA	14%
Residual	L_90_dBA	0%
Building	L_80_dBA	17%
Zone	L_80_dBA	66%
Sampling Date	L_80_dBA	17%
Residual	L_80_dBA	0%
Building	L_50_dBA	22%
Zone	L_50_dBA	56%
Sampling Date	L_50_dBA	22%
Residual	L_50_dBA	0%
Building	L_10_dBA	31%
Zone	L_10_dBA	37%
Sampling Date	L_10_dBA	31%
Residual	L_10_dBA	0%

Table Q3. Variance in sound NC max and RC measurements.

Factor	Sound Measure	Percentage
Building	L_90_NCMax	11%
Zone	L_90_NCMax	77%
Sampling Date	L_90_NCMax	11%
Residual	L_90_NCMax	0%
Building	L_80_NCMax	14%
Zone	L_80_NCMax	72%
Sampling Date	L_80_NCMax	14%
Residual	L_80_NCMax	0%
Building	L_50_NCMax	17%
Zone	L_50_NCMax	66%
Sampling Date	L_50_NCMax	17%
Residual	L_50_NCMax	0%
Building	L_10_NCMax	29%
Zone	L_10_NCMax	42%
Sampling Date	L_10_NCMax	29%
Residual	L_10_NCMax	0%
Building	L_90_RC	14%
Zone	L_90_RC	73%
Sampling Date	L_90_RC	13%
Residual	L_90_RC	0%
Building	L_80_RC	15%
Zone	L_80_RC	69%
Sampling Date	L_80_RC	15%
Residual	L_80_RC	0%
Building	L_50_RC	19%
Zone	L_50_RC	62%
Sampling Date	L_50_RC	19%
Residual	L_50_RC	0%
Building	L_10_RC	28%
Zone	L_10_RC	44%
Sampling Date	L_10_RC	28%
Residual	L_10_RC	0%

Q10. Statistical Results In Comparison Of Sound Measurements With Answers To The Occupant Perception Questionnaire For The Question "Over The Last Four Weeks I Would Rate The Sound Or Noise In My Work Area As Acceptable"

(Type = statistical analysis performed; Corr = correlation, yellow highlight = significant [p<0.05]; green highlight = moderately significant [0.05<p<0.075]).

Table Q4. Statistical results in comparison of sound measurements with answers to the occupant perception questionnaire for the question "over the last four weeks i would rate the sound or noise in my work area as acceptable" for building 1.

Variable	Type	Corr	p value
L_5_dBA	Pearson	0.639205	0.087935
L_5_dBA	Spearman	0.619471	0.101431
L_5_dBC	Pearson	0.128336	0.761998
L_5_dBC	Spearman	0.114708	0.786802
L_50_dBA	Pearson	0.746249	0.033468
L_50_dBA	Spearman	0.210132	0.418226
L_50_dBC	Pearson	0.105442	0.803756
L_50_dBC	Spearman	-0.25811	0.537104
L_95_dBA	Pearson	0.062286	0.883515
L_95_dBA	Spearman	0.361358	0.379126
L_95_dBC	Pearson	0.109636	0.796075
L_95_dBC	Spearman	-0.25811	0.537104

Table Q5. Statistical results in comparison of sound measurements with answers to the occupant perception questionnaire for the question "over the last four weeks i would rate the sound or noise in my work area as acceptable" for building 2.

Variable	Type	Corr	p value
L_5_dBA	Pearson	-0.39671	0.378247
L_5_dBA	Spearman	-0.5631	0.188095
L_5_dBC	Pearson	-0.10623	0.820675
L_5_dBC	Spearman	-0.31739	0.487912
L_50_dBA	Pearson	-0.34165	0.453239
L_50_dBA	Spearman	-0.5631	0.188095
L_50_dBC	Pearson	-0.04385	0.925625
L_50_dBC	Spearman	0.133097	0.776043
L_95_dBA	Pearson	-0.41458	0.355073
L_95_dBA	Spearman	-0.15357	0.742349
L_95_dBC	Pearson	0.120842	0.796347
L_95_dBC	Spearman	0.133097	0.776043

Table Q6 Statistical results in comparison of sound measurements with answers to the occupant perception questionnaire for the question "over the last four weeks i would rate the sound or noise in my work area as acceptable" for building 3.

Variable	Type	Corr	p value
L_5_dBA	Pearson	-0.69816	0.005488
L_5_dBA	Spearman	-0.74245	0.002356
L_5_dBC	Pearson	-0.41509	0.13997
L_5_dBC	Spearman	-0.22321	0.443039
L_50_dBA	Pearson	-0.73015	0.003026
L_50_dBA	Spearman	-0.75287	0.001885
L_50_dBC	Pearson	-0.39065	0.167271
L_50_dBC	Spearman	-0.22321	0.443039
L_95_dBA	Pearson	-0.73632	0.002673
L_95_dBA	Spearman	-0.73017	0.003025
L_95_dBC	Pearson	-0.34187	0.231548
L_95_dBC	Spearman	-0.21213	0.466578

Table Q7. Statistical results in comparison of sound measurements with answers to the occupant perception questionnaire for the question "over the last four weeks i would rate the sound or noise in my work area as acceptable" for building 4.

Variable	Type	Corr	p value
L_5_dBA	Pearson	0	1
L_5_dBA	Spearman	0.067598	0.796577
L_5_dBC	Pearson	0.18531	0.476429
L_5_dBC	Spearman	0.043972	0.866921
L_50_dBA	Pearson	0.210132	0.418226
L_50_dBA	Spearman	0.243486	0.346332
L_50_dBC	Pearson	0.247365	0.338458
L_50_dBC	Spearman	0.049222	0.851188
L_95_dBA	Pearson	0.079523	0.761593
L_95_dBA	Spearman	-0.04397	0.866921
L_95_dBC	Pearson	0.204531	0.431019
L_95_dBC	Spearman	0.040034	0.878752

Table Q8. Statistical results in comparison of sound measurements with answers to the occupant perception questionnaire for the question "over the last four weeks i would rate the sound or noise in my work area as acceptable" for building 5.

Variable	Type	Corr	p value
L_5_dBA	Pearson	-0.14587	0.528104
L_5_dBA	Spearman	-0.00837	0.971274
L_5_dBC	Pearson	0.016599	0.943068
L_5_dBC	Spearman	-0.00328	0.988757
L_50_dBA	Pearson	-0.10733	0.643321
L_50_dBA	Spearman	0.038214	0.869374
L_50_dBC	Pearson	0.023185	0.920538
L_50_dBC	Spearman	-0.01492	0.948815
L_95_dBA	Pearson	0	1
L_95_dBA	Spearman	0.059322	0.798394
L_95_dBC	Pearson	0.023769	0.918543
L_95_dBC	Spearman	-0.02366	0.91893

Table Q9. Statistical results in comparison of sound measurements with answers to the occupant perception questionnaire for the question "over the last four weeks i would rate the sound or noise in my work area as acceptable" for building 6.

Variable	Type	Corr	p value
L_5_dBA	Pearson	0.219742	0.142282
L_5_dBA	Spearman	0.133436	0.376663
L_5_dBC	Pearson	0.238694	0.110147
L_5_dBC	Spearman	0.279094	0.060337
L_50_dBA	Pearson	0.163888	0.276449
L_50_dBA	Spearman	0.097841	0.517709
L_50_dBC	Pearson	0.23607	0.114231
L_50_dBC	Spearman	0.279094	0.060337
L_95_dBA	Pearson	0.097429	0.519480
L_95_dBA	Spearman	0.146653	0.330777
L_95_dBC	Pearson	0.226883	0.129444
L_95_dBC	Spearman	0.213297	0.154656

Table Q10 Statistical results in comparison of sound measurements with answers to the occupant perception questionnaire for the question "over the last four weeks i would rate the sound or noise in my work area as acceptable" for building 7.

Variable	Type	Corr	p value
L_5_dBA	Pearson	0.046887	0.644906
L_5_dBA	Spearman	0.071886	0.479512
L_5_dBC	Pearson	0.010774	0.915707
L_5_dBC	Spearman	-0.10362	0.307436
L_50_dBA	Pearson	0.17181	0.089047
L_50_dBA	Spearman	0.153721	0.128731
L_50_dBC	Pearson	-0.0343	0.736088
L_50_dBC	Spearman	-0.13694	0.176491
L_95_dBA	Pearson	0.124047	0.221213
L_95_dBA	Spearman	0.204069	0.04276
L_95_dBC	Pearson	0.025119	0.805063
L_95_dBC	Spearman	0.054596	0.591458

Table Q11. Statistical results in comparison of sound measurements with answers to the occupant perception questionnaire for the question "over the last four weeks i would rate the sound or noise in my work area as acceptable" for building 8.

Variable	Type	Corr	p value
L_5_dBA	Pearson	-0.06888	0.668707
L_5_dBA	Spearman	0.010233	0.949371
L_5_dBC	Pearson	0.222894	0.161281
L_5_dBC	Spearman	0.23667	0.136272
L_50_dBA	Pearson	-0.00492	0.975651
L_50_dBA	Spearman	-0.01993	0.901584
L_50_dBC	Pearson	0.221158	0.164655
L_50_dBC	Spearman	0.23667	0.136272
L_95_dBA	Pearson	-0.11601	0.470092
L_95_dBA	Spearman	-0.09162	0.56889
L_95_dBC	Pearson	-0.05285	0.742799
L_95_dBC	Spearman	-0.02029	0.899819

Table Q12. Statistical results in comparison of sound measurements with answers to the occupant perception questionnaire for the question “over the last four weeks i would rate the sound or noise in my work area as acceptable” for building 9.

Variable	Type	Corr	p value
L_5_dBA	Pearson	-0.0447	0.736734
L_5_dBA	Spearman	0.07874	0.553344
L_5_dBC	Pearson	0.15512	0.240743
L_5_dBC	Spearman	0.16788	0.203739
L_50_dBA	Pearson	0.06712	0.613506
L_50_dBA	Spearman	0.16788	0.203739
L_50_dBC	Pearson	0.09462	0.475939
L_50_dBC	Spearman	0.07874	0.553344
L_95_dBA	Pearson	0.23425	0.074134
L_95_dBA	Spearman	0.24865	0.057561
L_95_dBC	Pearson	0.17201	0.192679
L_95_dBC	Spearman	-0.103	0.437593

Table Q13. Statistical results in comparison of sound measurements with answers to the occupant perception questionnaire for the question “over the last four weeks i would rate the sound or noise in my work area as acceptable” for building 10.

Variable	Type	Corr	p value
L_5_dBA	Pearson	0.147992	0.205115
L_5_dBA	Spearman	0.145156	0.214029
L_5_dBC	Pearson	0.125206	0.284475
L_5_dBC	Spearman	0.145156	0.214029
L_50_dBA	Pearson	0.131565	0.260526
L_50_dBA	Spearman	0.157931	0.175973
L_50_dBC	Pearson	0.121706	0.298259
L_50_dBC	Spearman	0.145156	0.214029
L_95_dBA	Pearson	0.004386	0.970206
L_95_dBA	Spearman	0.00162	0.988996
L_95 _dBC	Pearson	0.122608	0.294665
L_95 _dBC	Spearman	0.139107	0.233942

Q11. Statistical Results In Comparison Of Sound Measurements In With Answers To The Occupant Perception Questionnaire For The Question "Throughout The Course Of The Entire Workday, The Sounds Or Noise In My Work Area Fluctuates"

(Type = statistical analysis performed; Corr = correlation, yellow highlight = significant [p<0.05]; green highlight = moderately significant [0.05<p<0.075]).

Table Q14. Pearson and Spearman Tests Results for Individual Buildings

Bldg ID	Type	Corr	p value
1	Pearson	0.285779	0.492624
1	Spearman	0.258113	0.537104
2	Pearson	0.292009	0.525133
2	Spearman	0.048086	0.918461
3	Pearson	-0.16162	0.580941
3	Spearman	0.039647	0.892955
4	Pearson	0.553256	0.021237
4	Spearman	0.525468	0.030296
5	Pearson	-0.14598	0.52779
5	Spearman	-0.16042	0.487267
6	Pearson	0.111175	0.462
6	Spearman	0.105222	0.486463
7	Pearson	0.013732	0.89269
7	Spearman	0.069466	0.494466
8	Pearson	-0.07197	0.65478
8	Spearman	0.016214	0.919855
9	Pearson	0.039309	0.767543
9	Spearman	0.045759	0.73074
10	Pearson	0.130723	0.263615
10	Spearman	0.13318	0.254668

Q12. Statistical Results In Comparison Of Sound Measurements With Answers To The Occupant Perception Questionnaire For The Question "I Hear Sounds From Outside The Building (Airplanes, Traffic, Trains, Construction, Mechanical Equipment, Sirens, Etc.) In My Work Area"

(SndOSHear) with follow on questions concerning the sound affecting productivity (SndOSProdAffect), if the sound was annoying/distracting (SndOSAnnoy), and how soon the annoyance/distraction occurred (SndOSDistrWithin) and for how long (SndOSDistrFor) the annoyance/distraction continued

(Type = statistical analysis performed; Corr = correlation, yellow highlight = significant [$p<0.05$]; green highlight = moderately significant [$0.05<p<0.075$]).

Table Q15. Statistical results in comparison of sound measurements with answers to the occupant perception questionnaire for the question "i hear sounds from outside the building (airplanes, traffic, trains, construction, mechanical equipment, sirens, etc.) in my work area" for building 1.

Variable	Type	Corr	p value
SndOSHear	Pearson	-0.35642	0.386147
SndOSHear	Spearman	-0.45004	0.263195
SndOSProdAffect	Pearson	-0.24961	0.551056
SndOSProdAffect	Spearman	-0.2905	0.485186
SndOSAnnoy	Pearson	-0.22601	0.590436
SndOSAnnoy	Spearman	0.063786	0.880724
SndOSDistrWithin	Pearson	0.118435	0.823178
SndOSDistrWithin	Spearman	0.131165	0.804381
SndOSDistrFor	Pearson	0.16912	0.748738
SndOSDistrFor	Spearman	0.290323	0.576751

Table Q16. Statistical results in comparison of sound measurements with answers to the occupant perception questionnaire for the question "i hear sounds from outside the building (airplanes, traffic, trains, construction, mechanical equipment, sirens, etc.) in my work area" for building 2.

Variable	Type	Corr	p value
SndOSHear	Pearson	0.246018	0.594871
SndOSHear	Spearman	0.285727	0.53449
SndOSProdAffect	Pearson	0.928593	0.007466
SndOSProdAffect	Spearman	0.783349	0.065322
SndOSAnnoy	Pearson	0.894459	0.016120
SndOSAnnoy	Spearman	0.783349	0.065322
SndOSDistrWithin	Pearson	-1	
SndOSDistrWithin	Spearman	-1	
SndOSDistrFor	Pearson	-1	
SndOSDistrFor	Spearman	-1	

Table Q17. Statistical results in comparison of sound measurements with answers to the occupant perception questionnaire for the question “i hear sounds from outside the building (airplanes, traffic, trains, construction, mechanical equipment, sirens, etc.) in my work area” for building 3.

Variable	Type	Corr	p value
SndOSHear	Pearson	-0.18333	0.530418
SndOSHear	Spearman	-0.75000	0.002006
SndOSAnnoy	Pearson	0.148109	0.683025
SndOSAnnoy	Spearman	-0.04444	0.90297
SndOSProdAffect	Pearson	0.239423	0.505266
SndOSProdAffect	Spearman	0.026836	0.941339
SndOSDistrWithin	Pearson	-0.30877	0.551565
SndOSDistrWithin	Spearman	-0.65727	0.156069
SndOSDistrFor	Pearson	-0.21093	0.688298
SndOSDistrFor	Spearman	-0.42426	0.401788

Table Q18. Statistical results in comparison of sound measurements with answers to the occupant perception questionnaire for the question “i hear sounds from outside the building (airplanes, traffic, trains, construction, mechanical equipment, sirens, etc.) in my work area” for building g 4.

Variable	Type	Corr	p value
SndOSHear	Pearson	0.056954	0.828117
SndOSHear	Spearman	0.124274	0.634634
SndOSAnnoy	Pearson	0.151389	0.605417
SndOSAnnoy	Spearman	0.266391	0.357257
SndOSProdAffect	Pearson	0.111374	0.704649
SndOSProdAffect	Spearman	0.198380	0.496586
SndOSDistrWithin	Pearson	0.204424	0.571046
SndOSDistrWithin	Spearman	0.153624	0.671766
SndOSDistrFor	Pearson	0.252947	0.480742
SndOSDistrFor	Spearman	0.310517	0.382536

Table Q19. Statistical results in comparison of sound measurements with answers to the occupant perception questionnaire for the question “i hear sounds from outside the building (airplanes, traffic, trains, construction, mechanical equipment, sirens, etc.) in my work area” for building 5.

Variable	Type	Corr	p value
SndOSHear	Pearson	0.18592	0.419738
SndOSHear	Spearman	0.21749	0.343618
SndOSAnnoy	Pearson	0.19768	0.431709
SndOSAnnoy	Spearman	0.24749	0.322104
SndOSProdAffect	Pearson	-0.3944	0.105319
SndOSProdAffect	Spearman	-0.3962	0.103589
SndOSDistrWithin	Pearson	0.20705	0.441644
SndOSDistrWithin	Spearman	0.09805	0.717914
SndOSDistrFor	Pearson	0.15573	0.564671
SndOSDistrFor	Spearman	0.09415	0.728711

Table Q20. Statistical results in comparison of sound measurements with answers to the occupant perception questionnaire for the question “i hear sounds from outside the building (airplanes, traffic, trains, construction, mechanical equipment, sirens, etc.) in my work area” for building 6.

Variable	Type	Corr	p value
SndOSHear	Pearson	-0.11632	0.441416
SndOSHear	Spearman	-0.19947	0.183840
SndOSAnnoy	Pearson	-0.21812	0.264821
SndOSAnnoy	Spearman	-0.25174	0.196268
SndOSProdAffect	Pearson	-0.11479	0.560804
SndOSProdAffect	Spearman	0.039172	0.843120
SndOSDistrWithin	Pearson	-0.39221	0.119449
SndOSDistrWithin	Spearman	-0.28968	0.259398
SndOSDistrFor	Pearson	-0.43312	0.082443
SndOSDistrFor	Spearman	-0.39974	0.111895

Table Q21 Statistical results in comparison of sound measurements with answers to the occupant perception questionnaire for the question “i hear sounds from outside the building (airplanes, traffic, trains, construction, mechanical equipment, sirens, etc.) in my work area” for building 7.

Variable	Type	Corr	p value
SndOSHear	Pearson	0.235489	0.018954
SndOSHear	Spearman	0.144126	0.154660
SndOSAnnoy	Pearson	0.057356	0.613314
SndOSAnnoy	Spearman	0.044391	0.695805
SndOSProdAffect	Pearson	-0.06697	0.555058
SndOSProdAffect	Spearman	-0.06507	0.566329
SndOSDistrWithin	Pearson	-0.15470	0.246263
SndOSDistrWithin	Spearman	-0.08227	0.539262
SndOSDistrFor	Pearson	-0.08671	0.517497
SndOSDistrFor	Spearman	-0.07440	0.578881

Table Q22. Statistical results in comparison of sound measurements with answers to the occupant perception questionnaire for the question “i hear sounds from outside the building (airplanes, traffic, trains, construction, mechanical equipment, sirens, etc.) in my work area” for building 8.

Variable	Type	Corr	p value
SndOSHear	Pearson	-0.32372	0.038954
SndOSHear	Spearman	-0.42313	0.005845
SndOSAnnoy	Pearson	-0.22930	0.317387
SndOSAnnoy	Spearman	-0.18998	0.409465
SndOSProdAffect	Pearson	-0.05114	0.825764
SndOSProdAffect	Spearman	-0.07136	0.758568
SndOSDistrWithin	Pearson	-0.11809	0.700799
SndOSDistrWithin	Spearman	-0.02937	0.924111
SndOSDistrFor	Pearson	0.081203	0.792000
SndOSDistrFor	Spearman	0.134923	0.660319

Table Q23. Statistical results in comparison of sound measurements with answers to the occupant perception questionnaire for the question “i hear sounds from outside the building (airplanes, traffic, trains, construction, mechanical equipment, sirens, etc.) in my work area” for building 9.

Variable	Type	Corr	p value
SndOSHear	Pearson	-0.43795	0.000523
SndOSHear	Spearman	-0.29396	0.023833
SndOSAnnoy	Pearson	0.090919	0.557239
SndOSAnnoy	Spearman	0.216704	0.157678
SndOSProdAffect	Pearson	-0.15491	0.315369
SndOSProdAffect	Spearman	-0.05635	0.716351
SndOSDistrWithin	Pearson	-0.03095	0.862068
SndOSDistrWithin	Spearman	0.090978	0.608854
SndOSDistrFor	Pearson	-0.05348	0.763874
SndOSDistrFor	Spearman	0.052284	0.769017

Table Q24. Statistical results in comparison of sound measurements with answers to the occupant perception questionnaire for the question “i hear sounds from outside the building (airplanes, traffic, trains, construction, mechanical equipment, sirens, etc.) in my work area” for building 10.

Variable	Type	Corr	p value
SndOSHear	Pearson	-0.11841	0.311622
SndOSHear	Spearman	-0.11690	0.317899
SndOSAnnoy	Pearson	-0.00589	0.974896
SndOSAnnoy	Spearman	0.075250	0.687442
SndOSProdAffect	Pearson	-0.25493	0.166344
SndOSProdAffect	Spearman	-0.22206	0.229896
SndOSDistrWithin	Pearson	0.326046	0.119978
SndOSDistrWithin	Spearman	0.287187	0.173613
SndOSDistrFor	Pearson	0.197818	0.354147
SndOSDistrFor	Spearman	0.241364	0.255868

Q13. Statistical Results In Comparison Of Sound Measurements And The Cause Of The Sound Distraction

(Bldg ID = building identification; Type = statistical analysis performed; Corr = correlation, yellow highlight = significant [p<0.05]; green highlight = moderately significant [0.05<p<0.075]; n/a = not applicable as there were no responses to this question).

Table Q25. Results for "too loud" and L_99 minus L_50 for dBA.

Bldg ID	Type	Corr	p value
1	Pearson	0.161394	0.702600
1	Spearman	0.454699	0.257663
2	Pearson	0.567634	0.183780
2	Spearman	0.524554	0.226767
3	Pearson	n/a	n/a
3	Spearman	n/a	n/a
4	Pearson	0.513297	0.035091
4	Spearman	0.507651	0.037502
5	Pearson	0.104163	0.653192
5	Spearman	0.099449	0.668001
6	Pearson	-0.18179	0.226610
6	Spearman	-0.19589	0.192001
7	Pearson	-0.16368	0.105484
7	Spearman	-0.18448	0.067561
8	Pearson	0.142476	0.374204
8	Spearman	0.165128	0.302195
9	Pearson	-0.13568	0.305546
9	Spearman	-0.04655	0.726243
10	Pearson	-0.05682	0.628261
10	Spearman	-0.05186	0.658582

Table Q26. Results for "intermittent/unpredictable" and L_95 minus L_50 for dBA.

Bldg ID	Type	Corr	p value
1	Pearson	0.093056	0.826524
1	Spearman	0.255146	0.541958
2	Pearson	n/a	n/a
2	Spearman	n/a	n/a
3	Pearson	0.094299	0.748473
3	Spearman	-0.01972	0.946651
4	Pearson	-0.23703	0.359665
4	Spearman	-0.17186	0.509531
5	Pearson	-0.19470	0.397699
5	Spearman	-0.13229	0.567580
6	Pearson	0.050315	0.739833
6	Spearman	-0.05076	0.737611
7	Pearson	0.185226	0.066434
7	Spearman	0.188806	0.061261
8	Pearson	0.087062	0.588328
8	Spearman	0.071611	0.656374
9	Pearson	-0.12925	0.329233
9	Spearman	-0.16443	0.213334
10	Pearson	0.003346	0.977269
10	Spearman	-0.00577	0.960797

Table Q27. Results for "increases /decreases" and L_80 minus L_50 for dBA.

Bldg ID	Type	Corr	p value
1	Pearson	-0.51396	0.192587
1	Spearman	-0.59534	0.119450
2	Pearson	n/a	n/a
2	Spearman	n/a	n/a
3	Pearson	-0.09045	0.758460
3	Spearman	0.11007	0.707967
4	Pearson	-0.18729	0.471648
4	Spearman	-0.17186	0.509531
5	Pearson	-0.20949	0.362086
5	Spearman	-0.28347	0.213047
6	Pearson	-0.04449	0.769054
6	Spearman	-0.06967	0.645469
7	Pearson	0.054143	0.594543
7	Spearman	0.061433	0.545803
8	Pearson	0.128014	0.425084
8	Spearman	0.021257	0.895049
9	Pearson	0.246875	0.059430
9	Spearman	0.184888	0.160950
10	Pearson	0.022717	0.846604
10	Spearman	0	1

Table Q28. Results for “understandable” and L_90 minus L_50.

Bldg ID	Type	Corr	p value
1	Pearson	0.159698	0.705618
1	Spearman	0.255146	0.541958
2	Pearson	-0.12982	0.781459
2	Spearman	0.104911	0.822876
3	Pearson	n/a	n/a
3	Spearman	n/a	n/a
4	Pearson	0.438376	0.078382
4	Spearman	0.366072	0.148425
5	Pearson	-0.20167	0.380692
5	Spearman	-0.28347	0.213047
6	Pearson	n/a	n/a
6	Spearman	n/a	n/a
7	Pearson	-0.04382	0.666739
7	Spearman	0	1
8	Pearson	0.020789	0.897347
8	Spearman	0.103575	0.519297
9	Pearson	-0.13517	0.307393
9	Spearman	0.048476	0.715412
10	Pearson	0.182197	0.117702
10	Spearman	0.173174	0.137334

Q14. Statistical Results In Comparison Of Sound Measurements With Answers To The Occupant Perception Questionnaire For The Question "I Hear Sounds From Telephone/Speaker Phone Conversations That Carry Into My Work Area"

(SndTelHear) with follow on questions concerning the sound affecting productivity (SndTelProdAffect), if the sound was annoying/distracting (SndTelAnnoy), and how soon the annoyance/distraction occurred (SndTelDistrWithin) and for how long (SndTelDistrFor) the annoyance/distraction continued

(Type = statistical analysis performed; Corr = correlation, yellow highlight = significant [$p<0.05$]; green highlight = moderately significant [$0.05<p<0.075$]).

Table Q29. Statistical results in comparison of sound measurements with answers to the occupant perception questionnaire for the question "I hear sounds from telephone/speaker phone conversations that carry into my work area" for building 1

Variable	Type	Corr	p value
SndTelHear	Pearson	0.504866	0.201933
SndTelHear	Spearman	0.28026	0.501380
SndTelProdAffect	Pearson	-0.04618	0.913532
SndTelProdAffect	Spearman	0.269321	0.518911
SndTelAnnoy	Pearson	0.269851	0.518056
SndTelAnnoy	Spearman	0.594937	0.119766
SndTelDistrWithin	Pearson	-0.13751	0.768763
SndTelDistrWithin	Spearman	0.038837	0.934118
SndTelDistrFor	Pearson	0.117797	0.801406
SndTelDistrFor	Spearman	0.283069	0.538466

Table Q30. Statistical results in comparison of sound measurements with answers to the occupant perception questionnaire for the question "I hear sounds from telephone/speaker phone conversations that carry into my work area" for building 2.

Variable	Type	Corr	p value
SndTelHear	Pearson	-0.11263	0.810012
SndTelHear	Spearman	0.130847	0.779764
SndTelProdAffect	Pearson	0.354265	0.490833
SndTelProdAffect	Spearman	0.223906	0.669754
SndTelAnnoy	Pearson	0.518566	0.291875
SndTelAnnoy	Spearman	0.318182	0.538834
SndTelDistrWithin	Pearson	-0.42187	0.578133
SndTelDistrWithin	Spearman	-0.38889	0.611111
SndTelDistrFor	Pearson	-0.90999	0.090014
SndTelDistrFor	Spearman	-0.83333	0.166667

Table Q31. Statistical results in comparison of sound measurements with answers to the occupant perception questionnaire for the question "I hear sounds from telephone/speaker phone conversations that carry into my work area" for building 3.

Variable	Type	Corr	p value
SndTelHear	Pearson	-0.33665	0.239214
SndTelHear	Spearman	-0.47739	0.084299
SndTelProdAffect	Pearson	-0.07000	0.837950
SndTelProdAffect	Spearman	0.292877	0.382102
SndTelAnnoy	Pearson	-0.32913	0.322999
SndTelAnnoy	Spearman	0.142899	0.675106
SndTelDistrWithin	Pearson	0.171002	0.615160
SndTelDistrWithin	Spearman	0.287914	0.390590
SndTelDistrFor	Pearson	-0.06536	0.848573
SndTelDistrFor	Spearman	0.393422	0.231280

Table Q32. Statistical results in comparison of sound measurements with answers to the occupant perception questionnaire for the question "I hear sounds from telephone/speaker phone conversations that carry into my work area" for building 4.

Variable	Type	Corr	p value
SndTelHear	Pearson	-0.14054	0.590564
SndTelHear	Spearman	-0.13493	0.605637
SndTelProdAffect	Pearson	-0.05024	0.858869
SndTelProdAffect	Spearman	-0.03924	0.889585
SndTelAnnoy	Pearson	0.105124	0.709255
SndTelAnnoy	Spearman	0.155894	0.579028
SndTelDistrWithin	Pearson	0.144614	0.671395
SndTelDistrWithin	Spearman	0.080294	0.814458
SndTelDistrFor	Pearson	0.059849	0.861241
SndTelDistrFor	Spearman	0.090763	0.790702

Table Q33. Statistical results in comparison of sound measurements with answers to the occupant perception questionnaire for the question "I hear sounds from telephone/speaker phone conversations that carry into my work area" for building 5.

Variable	Type	Corr	p value
SndTelHear	Pearson	0.125565	0.587590
SndTelHear	Spearman	0.147542	0.523324
SndTelProdAffect	Pearson	-0.24431	0.328557
SndTelProdAffect	Spearman	-0.31176	0.207890
SndTelAnnoy	Pearson	-0.00968	0.969579
SndTelAnnoy	Spearman	-0.05803	0.819100
SndTelDistrWithin	Pearson	-0.16302	0.561574
SndTelDistrWithin	Spearman	-0.24189	0.385090
SndTelDistrFor	Pearson	-0.43168	0.108112
SndTelDistrFor	Spearman	-0.53409	0.040283

Table Q34. Statistical results in comparison of sound measurements with answers to the occupant perception questionnaire for the question "I hear sounds from telephone/speaker phone conversations that carry into my work area" for building 6.

Variable	Type	Corr	p value
SndTelHear	Pearson	0.142766	0.343893
SndTelHear	Spearman	-0.05154	0.733709
SndTelProdAffect	Pearson	-0.27303	0.072946
SndTelProdAffect	Spearman	-0.30689	0.042741
SndTelAnnoy	Pearson	-0.18042	0.241200
SndTelAnnoy	Spearman	-0.29614	0.050960
SndTelDistrWithin	Pearson	-0.00987	0.951810
SndTelDistrWithin	Spearman	-0.04139	0.799820
SndTelDistrFor	Pearson	-0.17377	0.283573
SndTelDistrFor	Spearman	-0.27432	0.086719

Table Q35. Statistical results in comparison of sound measurements with answers to the occupant perception questionnaire for the question "I hear sounds from telephone/speaker phone conversations that carry into my work area" for building 7.

Variable	Type	Corr	p value
SndTelHear	Pearson	0.009336	0.926928
SndTelHear	Spearman	-0.06584	0.517317
SndTelProdAffect	Pearson	0.110619	0.288508
SndTelProdAffect	Spearman	0.106004	0.309218
SndTelAnnoy	Pearson	0.032546	0.755490
SndTelAnnoy	Spearman	0.012143	0.907529
SndTelDistrWithin	Pearson	-0.16363	0.141868
SndTelDistrWithin	Spearman	-0.21844	0.048659
SndTelDistrFor	Pearson	0.07414	0.507989
SndTelDistrFor	Spearman	-0.04161	0.710504

Table Q36. Statistical results in comparison of sound measurements with answers to the occupant perception questionnaire for the question "I hear sounds from telephone/speaker phone conversations that carry into my work area" for building 8.

Variable	Type	Corr	p value
SndTelHear	Pearson	-0.12239	0.445859
SndTelHear	Spearman	-0.17783	0.265995
SndTelProdAffect	Pearson	0.065884	0.686278
SndTelProdAffect	Spearman	0.092829	0.568871
SndTelAnnoy	Pearson	0.092426	0.570557
SndTelAnnoy	Spearman	0.035771	0.826545
SndTelDistrWithin	Pearson	0.290261	0.095861
SndTelDistrWithin	Spearman	0.244447	0.163534
SndTelDistrFor	Pearson	0.214489	0.223173
SndTelDistrFor	Spearman	0.195136	0.268752

Table Q37. Statistical results in comparison of sound measurements with answers to the occupant perception questionnaire for the question "I hear sounds from telephone/speaker phone conversations that carry into my work area" for building 9.

Variable	Type	Corr	p value
SndTelHear	Pearson	0.23115	0.078163
SndTelHear	Spearman	0.274131	0.035639
SndTelProdAffect	Pearson	-0.02712	0.841276
SndTelProdAffect	Spearman	0.040738	0.763511
SndTelAnnoy	Pearson	0.092431	0.494072
SndTelAnnoy	Spearman	0.182455	0.174331
SndTelDistrWithin	Pearson	-0.14944	0.295253
SndTelDistrWithin	Spearman	-0.02192	0.878663
SndTelDistrFor	Pearson	0.053858	0.707395
SndTelDistrFor	Spearman	0.079816	0.577690

Table Q38 Statistical results in comparison of sound measurements with answers to the occupant perception questionnaire for the question "I hear sounds from telephone/speaker phone conversations that carry into my work area" for building 10.

Variable	Type	Corr	p value
SndTelHear	Pearson	-0.00929	0.936947
SndTelHear	Spearman	0.019067	0.871020
SndTelProdAffect	Pearson	-0.04518	0.712423
SndTelProdAffect	Spearman	-0.06842	0.576444
SndTelAnnoy	Pearson	0.007169	0.953377
SndTelAnnoy	Spearman	-0.03102	0.800245
SndTelDistrFor	Pearson	0.159326	0.212297
SndTelDistrFor	Spearman	0.102253	0.425192
SndTelDistrWithin	Pearson	-0.02426	0.850299
SndTelDistrWithin	Spearman	-0.02077	0.871645

Q15. Statistical Results In Comparison Of Sound Measurements And The Cause Of The Telephone/Speakerphone Distraction

(Bldg ID = building identification; Type = statistical analysis performed; Corr = correlation, yellow highlight = significant [p<0.05]; green highlight = moderately significant [0.05<p<0.075]; n/a = not applicable as there were no responses to this question).

Table Q39. Results for "too loud" and L_99 minus L_50 for dBA.

Bldg ID	Type	Corr	p value
1	Pearson	-0.16589	0.694610
1	Spearman	-0.12991	0.759138
2	Pearson	0.392977	0.383159
2	Spearman	0.487582	0.267032
3	Pearson	-0.03834	0.896478
3	Spearman	0.11007	0.707967
4	Pearson	0.000425	0.998708
4	Spearman	0	1
5	Pearson	0.274622	0.228300
5	Spearman	0.314922	0.164388
6	Pearson	0.175178	0.244242
6	Spearman	0.212295	0.156649
7	Pearson	-0.0387	0.703720
7	Spearman	-0.02009	0.843498
8	Pearson	0.143053	0.372252
8	Spearman	0.034335	0.831239
9	Pearson	-0.02796	0.833491
9	Spearman	0	1
10	Pearson	-0.09472	0.418889
10	Spearman	-0.08672	0.459436

Table Q40. Results for “intermittent/unpredictable” and L_95 minus L_50 for dBA.

Bldg ID	Type	Corr	p value
1	Pearson	n/a	n/a
1	Spearman	n/a	n/a
2	Pearson	n/a	n/a
2	Spearman	n/a	n/a
3	Pearson	-0.07218	0.806283
3	Spearman	0.207255	0.477113
4	Pearson	0.022541	0.931571
4	Spearman	0.104592	0.689528
5	Pearson	0.167554	0.467858
5	Spearman	0.150812	0.514054
6	Pearson	0.013898	0.926959
6	Spearman	-0.04061	0.788736
7	Pearson	-0.04331	0.670348
7	Spearman	0.013872	0.891601
8	Pearson	-0.01043	0.948375
8	Spearman	0.016361	0.919133
9	Pearson	0.003222	0.980679
9	Spearman	-0.0168	0.899501
10	Pearson	-0.0388	0.741042
10	Spearman	-0.04149	0.723780

Table Q41. Results for "increases /decreases" and L_80 minus L_50 for dBA.

Bldg ID	Type	Corr	p value
1	Pearson	n/a	n/a
1	Spearman	n/a	n/a
2	Pearson	n/a	n/a
2	Spearman	n/a	n/a
3	Pearson	-0.1499	0.609013
3	Spearman	-0.47697	0.084614
4	Pearson	-0.11536	0.659303
4	Spearman	-0.10459	0.689528
5	Pearson	0.213112	0.353657
5	Spearman	0.188982	0.411972
6	Pearson	0.041985	0.781747
6	Spearman	-0.08594	0.570093
7	Pearson	0.094176	0.353822
7	Spearman	0.082213	0.418523
8	Pearson	-0.04749	0.768108
8	Spearman	-0.04467	0.781537
9	Pearson	0.07708	0.561741
9	Spearman	0.11408	0.389608
10	Pearson	0.075713	0.518532
10	Spearman	0.058219	0.619795

Table Q42. Results for "understandable" and L_90 minus L_50 for dBA.

Bldg ID	Type	Corr	p value
1	Pearson	0.386271	0.344560
1	Spearman	0.232397	0.579690
2	Pearson	-0.60434	0.150628
2	Spearman	-0.81264	0.026310
3	Pearson	0.060453	0.837344
3	Spearman	-0.15776	0.590129
4	Pearson	0.21728	0.402196
4	Spearman	0.324067	0.204452
5	Pearson	-0.27345	0.230367
5	Spearman	-0.42021	0.057880
6	Pearson	-0.1564	0.299298
6	Spearman	-0.10272	0.496928
7	Pearson	-0.0298	0.769672
7	Spearman	-0.05484	0.589771
8	Pearson	-0.12862	0.422862
8	Spearman	-0.07862	0.625137
9	Pearson	0.103821	0.433908
9	Spearman	0.110256	0.405799
10	Pearson	0.116112	0.321183
10	Spearman	0.121339	0.299728

Q16. Statistical Results In Comparison Of Sound Measurements And The Question "I Hear Sounds From Conversations That Carry Into My Work Area"

… (SndConvHear) with follow on questions concerning the sound affecting productivity (SndConvProdAffect), if the sound was annoying/distracting (SndConvAnnoy), and how soon the annoyance/distraction occurred (SndConvDistrWithin) and for how long (SndConvDistrFor) the annoyance/distraction continued

(Bldg ID = building identification; Type = statistical analysis performed; Corr = correlation, yellow highlight = significant [$p<0.05$]; green highlight = moderately significant [$0.05<p<0.075$]; n/a = not applicable as there were no responses to this question).

Table Q43. Statistical results in comparison of sound measurements and the question "i hear sounds from conversations that carry into my work area" for building 1.

Variable	Type	Corr	p value
SndConvHear	Pearson	0.528707	0.177920
SndConvHear	Spearman	0.797468	0.017742
SndConvAnnoy	Pearson	0.511067	0.241103
SndConvAnnoy	Spearman	0.695522	0.082711
SndConvProdAffect	Pearson	-0.05403	0.908411
SndConvProdAffect	Spearman	0.258075	0.576321
SndConvDistrWithin	Pearson	-0.30852	0.551906
SndConvDistrWithin	Spearman	-0.43771	0.385361
SndConvDistrFor	Pearson	-0.20959	0.690214
SndConvDistrFor	Spearman	-0.18759	0.721913

Table Q44. Statistical results in comparison of sound measurements and the question "i hear sounds from conversations that carry into my work area" for building 2.

Variable	Type	Corr	p value
SndConvHear	Pearson	0.065534	0.888985
SndConvHear	Spearman	0.112621	0.810019
SndConvAnnoy	Pearson	0.212581	0.647210
SndConvAnnoy	Spearman	-0.00943	0.983985
SndConvProdAffect	Pearson	0.067524	0.885629
SndConvProdAffect	Spearman	0	1
SndConvDistrWithin	Pearson	0.105384	0.866069
SndConvDistrWithin	Spearman	0.25	0.685038
SndConvDistrFor	Pearson	-0.14612	0.814621
SndConvDistrFor	Spearman	-0.15811	0.799525

Table Q45. Statistical results in comparison of sound measurements and the question “i hear sounds from conversations that carry into my work area” for building 3.

Variable	Type	Corr	p value
SndConvHear	Pearson	-0.73872	0.002545
SndConvHear	Spearman	-0.42297	0.131851
SndConvAnnoy	Pearson	-0.17281	0.572357
SndConvAnnoy	Spearman	0.321052	0.284810
SndConvProdAffect	Pearson	-0.13454	0.661241
SndConvProdAffect	Spearman	0.228927	0.451861
SndConvDistrWithin	Pearson	-0.21381	0.483041
SndConvDistrWithin	Spearman	0.103679	0.736069
SndConvDistrFor	Pearson	-0.37508	0.206643
SndConvDistrFor	Spearman	0.278549	0.356761

Table Q46. Statistical results in comparison of sound measurements and the question “i hear sounds from conversations that carry into my work area” for building 4.

Variable	Type	Corr	p value
SndConvHear	Pearson	-0.07881	0.763681
SndConvHear	Spearman	-0.06263	0.811270
SndConvAnnoy	Pearson	0.078312	0.781462
SndConvAnnoy	Spearman	0.094747	0.736965
SndConvProdAffect	Pearson	0.150273	0.592950
SndConvProdAffect	Spearman	0.06055	0.830266
SndConvDistrWithin	Pearson	0.20166	0.508822
SndConvDistrWithin	Spearman	0.125251	0.683487
SndConvDistrFor	Pearson	0.574285	0.040108
SndConvDistrFor	Spearman	0.609904	0.026873

Table Q47. Statistical results in comparison of sound measurements and the question “i hear sounds from conversations that carry into my work area” for building 5.

Variable	Type	Corr	p value
SndConvHear	Pearson	0.360662	0.108240
SndConvHear	Spearman	0.362826	0.105985
SndConvAnnoy	Pearson	0.162805	0.480744
SndConvAnnoy	Spearman	0.084865	0.714552
SndConvProdAffect	Pearson	-0.01204	0.958700
SndConvProdAffect	Spearman	-0.15954	0.489694
SndConvDistrWithin	Pearson	0.039099	0.881566
SndConvDistrWithin	Spearman	-0.03659	0.889116
SndConvDistrFor	Pearson	-0.40555	0.106298
SndConvDistrFor	Spearman	-0.3759	0.137011

Table Q48. Statistical results in comparison of sound measurements and the question “i hear sounds from conversations that carry into my work area” for building 6.

Variable	Type	Corr	p value
SndConvHear	Pearson	0.186093	0.215620
SndConvHear	Spearman	0.005305	0.972087
SndConvAnnoy	Pearson	-0.11379	0.451478
SndConvAnnoy	Spearman	-0.24872	0.095559
SndConvProdAffect	Pearson	-0.1554	0.302416
SndConvProdAffect	Spearman	-0.24088	0.106824
SndConvDistrWithin	Pearson	-0.03794	0.818635
SndConvDistrWithin	Spearman	-0.0524	0.751399
SndConvDistrFor	Pearson	-0.30492	0.059091
SndConvDistrFor	Spearman	-0.34426	0.031870

Table Q49. Statistical results in comparison of sound measurements and the question “i hear sounds from conversations that carry into my work area” for building 7.

Variable	Type	Corr	p value
SndConvHear	Pearson	0.044515	0.661743
SndConvHear	Spearman	-0.03553	0.726973
SndConvAnnoy	Pearson	0.090461	0.378209
SndConvAnnoy	Spearman	0.052212	0.611514
SndConvProdAffect	Pearson	0.140882	0.168695
SndConvProdAffect	Spearman	0.149952	0.142644
SndConvDistrWithin	Pearson	-0.11809	0.303142
SndConvDistrWithin	Spearman	0.011238	0.922208
SndConvDistrFor	Pearson	0.106259	0.354485
SndConvDistrFor	Spearman	0.055050	0.632150

Table Q50. Statistical results in comparison of sound measurements and the question “i hear sounds from conversations that carry into my work area” for building 8.

Variable	Type	Corr	p value
SndConvHear	Pearson	0.015406	0.923839
SndConvHear	Spearman	0.032749	0.838929
SndConvAnnoy	Pearson	0.03781	0.814440
SndConvAnnoy	Spearman	0.091192	0.570688
SndConvProdAffect	Pearson	-0.0034	0.983186
SndConvProdAffect	Spearman	0.067967	0.672858
SndConvDistrWithin	Pearson	0.187482	0.304181
SndConvDistrWithin	Spearman	0.198669	0.275695
SndConvDistrFor	Pearson	0.132086	0.471139
SndConvDistrFor	Spearman	0.09315	0.612001

Table Q51. Statistical results in comparison of sound measurements and the question “i hear sounds from conversations that carry into my work area” for building 9.

Variable	Type	Corr	p value
SndConvHear	Pearson	0.391823	0.002148
SndConvHear	Spearman	0.451778	0.000328
SndConvAnnoy	Pearson	0.124438	0.352014
SndConvAnnoy	Spearman	0.172839	0.194481
SndConvProdAffect	Pearson	0.027626	0.836909
SndConvProdAffect	Spearman	0.028961	0.829139
SndConvDistrWithin	Pearson	-0.19011	0.190741
SndConvDistrWithin	Spearman	-0.09836	0.501335
SndConvDistrFor	Pearson	0.089918	0.538936
SndConvDistrFor	Spearman	0.147478	0.311902

Table Q52. Statistical results in comparison of sound measurements and the question “i hear sounds from conversations that carry into my work area” for building 10.

Variable	Type	Corr	p value
SndConvHear	Pearson	0.037604	0.748738
SndConvHear	Spearman	0.005957	0.959546
SndConvAnnoy	Pearson	0.051526	0.660640
SndConvAnnoy	Spearman	0.031714	0.787076
SndConvProdAffect	Pearson	-0.01275	0.913572
SndConvProdAffect	Spearman	0.009255	0.937184
SndConvDistrWithin	Pearson	-0.05864	0.637360
SndConvDistrWithin	Spearman	-0.06170	0.619906
SndConvDistrFor	Pearson	0.019782	0.873754
SndConvDistrFor	Spearman	0.033577	0.787356

Q17. Statistical Results In Comparison Of Sound Measurements And The Cause Of Conversation Distraction

(Bldg ID = building identification; Type = statistical analysis performed; Corr = correlation, yellow highlight = significant [$p<0.05$]; green highlight = moderately significant [$0.05<p<0.075$]; n/a = not applicable as there were no responses to this question).

Table Q53. Results for "too loud" and L_99 minus L_50 for SIL.

Bldg ID	Type	Corr	P value
1	Pearson	-0.03677	0.931127
1	Spearman	0.389742	0.339863
2	Pearson	0.392977	0.383159
2	Spearman	0.487582	0.267032
3	Pearson	-0.10853	0.711905
3	Spearman	0.092113	0.754137
4	Pearson	0.338169	0.184304
4	Spearman	0.270056	0.294503
5	Pearson	0.228588	0.318931
5	Spearman	0.386795	0.083249
5	Pearson	0.000354	0.998138
5	Spearman	-0.00342	0.981982
7	Pearson	-0.04809	0.636416
7	Spearman	-0.07968	0.433054
8	Pearson	-0.04887	0.761557
8	Spearman	-0.02573	0.873114
9	Pearson	-0.08312	0.531378
9	Spearman	-0.07501	0.572308
10	Pearson	-0.09829	0.401472
10	Spearman	-0.07247	0.536635

Table Q54. Results for "intermittent/unpredictable" and L_95 minus L_50 for SIL

Bldg ID	Type	Corr	p value
1	Pearson	n/a	n/a
1	Spearman	n/a	n/a
2	Pearson	n/a	n/a
2	Spearman	n/a	n/a
3	Pearson	-0.03834	0.896478
3	Spearman	0.11007	0.707967
4	Pearson	-0.22163	0.392611
4	Spearman	-0.17753	0.495454
5	Pearson	n/a	n/a
5	Spearman	n/a	n/a
6	Pearson	-0.07397	0.625182
6	Spearman	-0.12292	0.415750
7	Pearson	0.076736	0.450293
7	Spearman	0.110845	0.274719
8	Pearson	-0.02395	0.881852
8	Spearman	0.028718	0.858539
9	Pearson	0.062121	0.640209
9	Spearman	0.048476	0.715412
10	Pearson	-0.04325	0.712555
10	Spearman	-0.05469	0.641183

Table Q55. Results for "increases /decreases" and L_95 minus L_50 for SIL.

Bldg ID	Type	Corr	p value
1	Pearson	n/a	n/a
1	Spearman	n/a	n/a
2	Pearson	0.566149	0.185189
2	Spearman	0.524554	0.226767
3	Pearson	-0.08660	0.768474
3	Spearman	0.146760	0.616615
4	Pearson	n/a	n/a
4	Spearman	n/a	n/a
5	Pearson	-0.07466	0.747729
5	Spearman	0.056695	0.807158
6	Pearson	n/a	n/a
6	Spearman	n/a	n/a
7	Pearson	-0.02512	0.805044
7	Spearman	0.095572	0.346699
8	Pearson	-0.06291	0.695959
8	Spearman	-0.10674	0.506532
9	Pearson	-0.07319	0.581701
9	Spearman	-0.03005	0.821268
10	Pearson	0.013945	0.905481
10	Spearman	-0.00479	0.967491

Table Q56. Results for “understandable” and L_95 minus L_50 for SIL.

Bldg ID	Type	Corr	p value
1	Pearson	0.379225	0.354183
1	Spearman	0.168763	0.689526
2	Pearson	-0.60434	0.150628
2	Spearman	-0.81264	0.026310
3	Pearson	0	1
3	Spearman	0.037796	0.897927
4	Pearson	-0.41578	0.096936
4	Spearman	-0.40508	0.106741
5	Pearson	-0.04717	0.839102
5	Spearman	-0.21733	0.343984
6	Pearson	-0.14229	0.345511
6	Spearman	-0.24097	0.106694
7	Pearson	-0.00327	0.974399
7	Spearman	-0.00417	0.967321
8	Pearson	-0.02082	0.897194
8	Spearman	-0.04492	0.780323
9	Pearson	0.085347	0.520410
9	Spearman	0.134542	0.309653
10	Pearson	0.121672	0.298396
10	Spearman	0.110687	0.344460

Q18. Statistical Results In Comparison Of Sound Measurements And The Question "I Hear Sounds From Piped In Music Or Masking Sounds In My Work Area"

… (SndTelHear) with follow on questions concerning the sound affecting productivity (SndMusProdAffect), if the sound was annoying/distracting (SndMusAnnoy), and how soon the annoyance/distraction occurred (SndMusDistrWithin) and for how long (SndMusDistrFor) the annoyance/distraction continued

(Bldg ID = building identification; Type = statistical analysis performed; Corr = correlation, yellow highlight = significant [$p<0.05$]; green highlight = moderately significant [$0.05<p<0.075$]; n/a = not applicable as there were no responses to this question; nd = not done).

Table Q57. Statistical Results In Comparison Of Sound Measurements And The Question "I Hear Sounds From Piped In Music Or Masking Sounds In My Work Area" For Building 1.

Variable	Type	Corr	p value
SndMusHear	Pearson	0	1
SndMusHear	Spearman	0	1
SndMusAnnoy	Pearson	1	
SndMusAnnoy	Spearman	1	
SndMusDistrWithin	Pearson	n/a	n/a
SndMusDistrWithin	Spearman	n/a	n/a
SndMusDistrFor	Pearson	n/a	n/a
SndMusDistrFor	Spearman	n/a	n/a
SndMusProdAffect	Pearson	Nd	nd
SndMusProdAffect	Spearman	Nd	nd

Table Q58. Statistical Results In Comparison Of Sound Measurements And The Question "I Hear Sounds From Piped In Music Or Masking Sounds In My Work Area" for Building 2.

Variable	Type	Corr	p value
SndMusHear	Pearson	n/a	n/a
SndMusHear	Spearman	n/a	n/a
SndMusAnnoy	Pearson	n/a	n/a
SndMusAnnoy	Spearman	n/a	n/a
SndMusDistrWithin	Pearson	n/a	n/a
SndMusDistrWithin	Spearman	n/a	n/a
SndMusDistrFor	Pearson	n/a	n/a
SndMusDistrFor	Spearman	n/a	n/a
SndMusProdAffect	Pearson	Nd	nd
SndMusProdAffect	Spearman	Nd	nd

Table Q59. Statistical Results In Comparison Of Sound Measurements And The Question "I Hear Sounds From Piped In Music Or Masking Sounds In My Work Area"for Building 3.

Variable	Type	Corr	p value
SndMusHear	Pearson	-0.0456	0.876975
SndMusHear	Spearman	0.329412	0.250104
SndMusAnnoy	Pearson	n/a	n/a
SndMusAnnoy	Spearman	n/a	n/a
SndMusDistrWithin	Pearson	n/a	n/a
SndMusDistrWithin	Spearman	n/a	n/a
SndMusDistrFor	Pearson	n/a	n/a
SndMusDistrFor	Spearman	n/a	n/a
SndMusProdAffect	Pearson	nd	nd
SndMusProdAffect	Spearman	nd	nd

Table Q60. Statistical Results In Comparison Of Sound Measurements And The Question "I Hear Sounds From Piped In Music Or Masking Sounds In My Work Area"for Building 4.

Variable	Type	Corr	p value
SndMusHear	Pearson	0.002593	0.992120
SndMusHear	Spearman	0.056814	0.828534
SndMusAnnoy	Pearson	-0.12249	0.817184
SndMusAnnoy	Spearman	-0.18759	0.721913
SndMusDistrWithin	Pearson	-0.88081	0.313994
SndMusDistrWithin	Spearman	-0.86603	0.333333
SndMusDistrFor	Pearson	-0.88081	0.313994
SndMusDistrFor	Spearman	-0.86603	0.333333
SndMusProdAffect	Pearson	Nd	nd
SndMusProdAffect	Spearman	Nd	nd

Table Q61. Statistical Results In Comparison Of Sound Measurements And The Question "I Hear Sounds From Piped In Music Or Masking Sounds In My Work Area"for Building 5.

Variable	Type	Corr	p value
SndMusHear	Pearson	n/a	n/a
SndMusHear	Spearman	n/a	n/a
SndMusAnnoy	Pearson	n/a	n/a
SndMusAnnoy	Spearman	n/a	n/a
SndMusDistrWithin	Pearson	n/a	n/a
SndMusDistrWithin	Spearman	n/a	n/a
SndMusDistrFor	Pearson	n/a	n/a
SndMusDistrFor	Spearman	n/a	n/a
SndMusProdAffect	Pearson	nd	nd
SndMusProdAffect	Spearman	nd	nd

Table Q62. Statistical Results In Comparison Of Sound Measurements And The Question "I Hear Sounds From Piped In Music Or Masking Sounds In My Work Area"for Building 6.

Variable	Type	Corr	p value
SndMusHear	Pears	-0.20152	0.179281
SndMusHear	Spear	-0.12022	0.426121
SndMusAnnoy	Pears	0.330349	0.123672
SndMusAnnoy	Spear	0.347612	0.104105
SndMusDistrWithin	Pears	-0.12770	0.663522
SndMusDistrWithin	Spear	-0.28369	0.325650
SndMusDistrFor	Pears	0.304638	0.289592
SndMusDistrFor	Spear	0.221578	0.446470
SndMusProdAffect	Pearson	nd	nd
SndMusProdAffect	Spearman	nd	nd

Table Q63. Statistical Results In Comparison Of Sound Measurements And The Question "I Hear Sounds From Piped In Music Or Masking Sounds In My Work Area"for Building 7.

Variable	Type	Corr	p value
SndMusHear	Pears	-0.00895	0.929968
SndMusHear	Spear	0.036246	0.721708
SndMusAnnoy	Pears	-0.04915	0.807666
SndMusAnnoy	Spear	-0.07916	0.694700
SndMusDistrWithin	Pears	-0.35433	0.178136
SndMusDistrWithin	Spear	-0.33488	0.204843
SndMusDistrFor	Pears	-0.07315	0.787744
SndMusDistrFor	Spear	-0.02356	0.930974
SndMusProdAffect	Pearson	nd	nd
SndMusProdAffect	Spearman	nd	nd

Table Q64. Statistical Results In Comparison Of Sound Measurements And The Question "I Hear Sounds From Piped In Music Or Masking Sounds In My Work Area"for Building 8.

Variable	Type	Corr	p value
SndMusHear	Pears	-0.26169	0.098385
SndMusHear	Spear	0.046734	0.771702
SndMusAnnoy	Pears	-0.50385	0.248942
SndMusAnnoy	Spear	-0.38464	0.394229
SndMusDistrWithin	Pears	-0.23533	0.653525
SndMusDistrWithin	Spear	0.098374	0.852915
SndMusDistrFor	Pears	-0.67438	0.141783
SndMusDistrFor	Spear	-0.76667	0.075315
SndMusProdAffect	Pearson	nd	nd
SndMusProdAffect	Spearman	nd	nd

Table Q65. Statistical Results In Comparison Of Sound Measurements And The Question "I Hear Sounds From Piped In Music Or Masking Sounds In My Work Area"for Building 9.

Variable	Type	Corr	p value
SndMusHear	Pears	0.011108	0.933453
SndMusHear	Spear	-0.08568	0.518756
SndMusAnnoy	Pears	0.365502	0.015945
SndMusAnnoy	Spear	0.274030	0.075372
SndMusDistrWithin	Pears	0.048341	0.826622
SndMusDistrWithin	Spear	0.150775	0.492267
SndMusDistrFor	Pears	0.186063	0.395312
SndMusDistrFor	Spear	-0.00295	0.989358
SndMusProdAffect	Pearson	nd	nd
SndMusProdAffect	Spearman	nd	nd

Table Q66. Statistical Results In Comparison Of Sound Measurements And The Question "I Hear Sounds From Piped In Music Or Masking Sounds In My Work Area"of Building 10.

Variable	Type	Corr	p value
SndMusHear	Pears	-0.04476	0.702948
SndMusHear	Spear	-0.10085	0.389269
SndMusAnnoy	Pears	-0.09413	0.771059
SndMusAnnoy	Spear	-0.2514	0.430578
SndMusDistrWithin	Pears	-0.07266	0.852634
SndMusDistrWithin	Spear	0.123349	0.751879
SndMusDistrFor	Pears	0.266205	0.488704
SndMusDistrFor	Spear	0.203548	0.599387
SndMusProdAffect	Pearson	nd	nd
SndMusProdAffect	Spearman	nd	nd

Q19. Statistical Results In Comparison Of Sound Measurements And The Cause Of The Piped In Music Or Masking Sound Distraction

(Bldg ID = building identification; Type = statistical analysis performed; Corr = correlation, yellow highlight = significant [p<0.05]; green highlight = moderately significant [0.05<p<0.075]; n/a = not applicable as there were no responses to this question).

Table Q67. Results for "too loud" and L_80 minus L_10 for dBA.

Bldg ID	Type	Corr	p value
1	Pearson	0.20589	0.624727
1	Spearman	0.425243	0.293576
2	Pearson	n/a	n/a
2	Spearman	n/a	n/a
3	Pearson	-0.14297	0.625850
3	Spearman	-0.21138	0.468190
4	Pearson	n/a	n/a
4	Spearman	n/a	n/a
5	Pearson	n/a	n/a
5	Spearman	n/a	n/a
6	Pearson	-0.11451	0.448592
6	Spearman	-0.07248	0.632161
7	Pearson	0.059203	0.560506
7	Spearman	0.055082	0.588154
8	Pearson	-0.25326	0.110113
8	Spearman	-0.27691	0.079655
9	Pearson	-0.18299	0.165362
9	Spearman	-0.16802	0.203363
10	Pearson	-0.26330	0.022468
10	Spearman	-0.29637	0.009828

Table Q68. Results for “intermittent/unpredictable” and L_80 minus L_50 for dBA.

Bldg ID	Type	Corr	p value
1	Pearson	n/a	n/a
1	Spearman	n/a	n/a
2	Pearson	n/a	n/a
2	Spearman	n/a	n/a
3	Pearson	n/a	n/a
3	Spearman	n/a	n/a
4	Pearson	-0.18729	0.471648
4	Spearman	-0.17186	0.509531
5	Pearson	n/a	n/a
5	Spearman	n/a	n/a
6	Pearson	0.241657	0.105669
6	Spearman	0.257399	0.084176
7	Pearson	0.035503	0.727185
7	Spearman	-0.02795	0.783591
8	Pearson	0.250788	0.113750
8	Spearman	0.191316	0.230823
9	Pearson	-0.08242	0.534854
9	Spearman	0.060096	0.651171
10	Pearson	0.212712	0.066917
10	Spearman	0.186671	0.108804

Table Q69. Results for "increases /decreases" and L_80 minus L_50 for dBA.

Bldg ID	Type	Corr	p value
1	Pearson	n/a	n/a
1	Spearman	n/a	n/a
2	Pearson	n/a	n/a
2	Spearman	n/a	n/a
3	Pearson	-0.14321	0.625257
3	Spearman	-0.29352	0.308431
4	Pearson	n/a	n/a
4	Spearman	n/a	n/a
5	Pearson	n/a	n/a
5	Spearman	n/a	n/a
6	Pearson	-0.06363	0.674382
6	Spearman	-0.09964	0.510008
7	Pearson	n/a	n/a
7	Spearman	n/a	n/a
8	Pearson	n/a	n/a
8	Spearman	n/a	n/a
9	Pearson	-0.13003	0.326322
9	Spearman	-0.12907	0.329914
10	Pearson	0.084206	0.472588
10	Spearman	0.09813	0.402264

Table Q70. Results for "understandable" and L_80 minus L_50 for dBA.

Bldg ID	Type	Corr	p value
1	Pearson	n/a	n/a
1	Spearman	n/a	n/a
2	Pearson	n/a	n/a
2	Spearman	n/a	n/a
3	Pearson	n/a	n/a
3	Spearman	n/a	n/a
4	Pearson	n/a	n/a
4	Spearman	n/a	n/a
5	Pearson	n/a	n/a
5	Spearman	n/a	n/a
6	Pearson	n/a	n/a
6	Spearman	n/a	n/a
7	Pearson	-0.08346	0.411485
7	Spearman	-0.11337	0.263846
8	Pearson	n/a	n/a
8	Spearman	n/a	n/a
9	Pearson	0.042014	0.752041
9	Spearman	0.11408	0.389608
10	Pearson	n/a	n/a
10	Spearman	n/a	n/a

Q20. Statistical Results In Comparison Of Sound Measurements And The Question "I Hear Sounds From Office Equipment In My Work Area"

… (SndEquipHear) with follow on questions concerning the sound affecting productivity (SndEquipProdAffect), if the sound was annoying/distracting (SndEquipAnnoy), and how soon the annoyance/distraction occurred (SndEquipDistrWithin) and for how long (SndEquipDistrFor) the annoyance/distraction continued

(Bldg ID = building identification; Type = statistical analysis performed; Corr = correlation, yellow highlight = significant [$p<0.05$]; green highlight = moderately significant [$0.05<p<0.075$]; n/a = not applicable as there were no responses to this question).

Table Q71. Statistical Results In Comparison Of Sound Measurements And The Question "I Hear Sounds From Office Equipment In My Work Area" for Building 1.

Variable	Type	Corr	p value
SndEquipHear	Pearson	0.697724	0.054341
SndEquipHear	Spearman	0.718185	0.044794
SndEquipAnnoy	Pearson	0.564618	0.243072
SndEquipAnnoy	Spearman	0.338823	0.511215
SndEquipProdAffect	Pearson	0.660195	0.153583
SndEquipProdAffect	Spearman	0.562775	0.244957
SndEquipDistrWithi	Pearson	0.504524	0.386021
SndEquipDistrWithi	Spearman	0.516185	0.373253
SndEquipDistrFor	Pearson	0.303130	0.620038
SndEquipDistrFor	Spearman	0.176777	0.776099

Table Q72. Statistical Results In Comparison Of Sound Measurements And The Question "I Hear Sounds From Office Equipment In My Work Area" for Building 2.

Variable	Type	Corr	p value
SndEquipHear	Pearson	0.063329	0.892705
SndEquipHear	Spearman	0.047170	0.920011
SndEquipAnnoy	Pearson	0.808056	0.097989
SndEquipAnnoy	Spearman	0.789474	0.112222
SndEquipProdAffect	Pearson	0.640070	0.244736
SndEquipProdAffect	Spearman	0.459627	0.436097
SndEquipDistrWithi	Pearson	-0.20217	0.797828
SndEquipDistrWithi	Spearman	0.055556	0.944444
SndEquipDistrFor	Pearson	-0.52476	0.475244
SndEquipDistrFor	Spearman	-0.50000	0.500000

Table Q73. Statistical Results In Comparison Of Sound Measurements And The Question "I Hear Sounds From Office Equipment In My Work Area" for Building 3.

Variable	Type	Corr	p value
SndEquipHear	Pearson	0.204327	0.483496
SndEquipHear	Spearman	0.390439	0.167521
SndEquipAnnoy	Pearson	0.224054	0.629109
SndEquipAnnoy	Spearman	0.328165	0.472397
SndEquipProdAffect	Pearson	0.224054	0.629109
SndEquipProdAffect	Spearman	0.328165	0.472397
SndEquipDistrWithi	Pearson	1	
SndEquipDistrWithi	Spearman	1	
SndEquipDistrFor	Pearson	1	
SndEquipDistrFor	Spearman	1	

Table Q74. Statistical Results In Comparison Of Sound Measurements And The Question "I Hear Sounds From Office Equipment In My Work Area" for Building 4.

Variable	Type	Corr	p value
SndEquipHear	Pearson	-0.31413	0.219482
SndEquipHear	Spearman	-0.41625	0.096523
SndEquipAnnoy	Pearson	0.253617	0.451749
SndEquipAnnoy	Spearman	0.435692	0.180413
SndEquipProdAffect	Pearson	0.233583	0.489398
SndEquipProdAffect	Spearman	0.381025	0.247625
SndEquipDistrWithi	Pearson	0.019229	0.967361
SndEquipDistrWithi	Spearman	-0.19627	0.673182
SndEquipDistrFor	Pearson	0.387455	0.390476
SndEquipDistrFor	Spearman	0.257248	0.577588

Table Q75. Statistical Results In Comparison Of Sound Measurements And The Question "I Hear Sounds From Office Equipment In My Work Area" for Building 5.

Variable	Type	Corr	p value
SndEquipHear	Pearson	-0.2985	0.188643
SndEquipHear	Spearman	-0.2718	0.233271
SndEquipAnnoy	Pearson	-0.1179	0.701156
SndEquipAnnoy	Spearman	-0.2191	0.471972
SndEquipProdAffect	Pearson	-0.0385	0.900439
SndEquipProdAffect	Spearman	-0.2263	0.457167
SndEquipDistrWithi	Pearson	-0.0743	0.874064
SndEquipDistrWithi	Spearman	-0.2504	0.58797
SndEquipDistrFor	Pearson	-0.3408	0.454397
SndEquipDistrFor	Spearman	-0.5114	0.240726

Table Q76. Statistical Results In Comparison Of Sound Measurements And The Question "I Hear Sounds From Office Equipment In My Work Area" for Building 6.

Variable	Type	Corr	p value
SndEquipHear	Pearson	0.223015	0.136286
SndEquipHear	Spearman	0.191777	0.201677
SndEquipAnnoy	Pearson	0.08895	0.672425
SndEquipAnnoy	Spearman	0.033772	0.872674
SndEquipProdAffect	Pearson	0.056824	0.787321
SndEquipProdAffect	Spearman	0.036457	0.862644
SndEquipDistrWithi	Pearson	-0.20984	0.491399
SndEquipDistrWithi	Spearman	-0.03451	0.910874
SndEquipDistrFor	Pearson	-0.09544	0.756444
SndEquipDistrFor	Spearman	-0.09737	0.751654

Table Q77. Statistical Results In Comparison Of Sound Measurements And The Question "I Hear Sounds From Office Equipment In My Work Area" for Building 7.

Variable	Type	Corr	p value
SndEquipHear	Pearson	-0.04650	0.647624
SndEquipHear	Spearman	-0.10667	0.293318
SndEquipAnnoy	Pearson	0.063454	0.576040
SndEquipAnnoy	Spearman	-0.00840	0.941081
SndEquipProdAffect	Pearson	0.163912	0.146265
SndEquipProdAffect	Spearman	0.103795	0.359542
SndEquipDistrWithi	Pearson	0.002998	0.985748
SndEquipDistrWithi	Spearman	0.154672	0.353819
SndEquipDistrFor	Pearson	0.210824	0.203897
SndEquipDistrFor	Spearman	0.137020	0.412039

Table Q78. Statistical Results In Comparison Of Sound Measurements And The Question "I Hear Sounds From Office Equipment In My Work Area" for Building 8.

Variable	Type	Corr	p value
SndEquipHear	Pearson	0.063316	0.694115
SndEquipHear	Spearman	0.064022	0.690874
SndEquipAnnoy	Pearson	-0.10959	0.518485
SndEquipAnnoy	Spearman	-0.16401	0.332070
SndEquipProdAffect	Pearson	-0.15766	0.351367
SndEquipProdAffect	Spearman	-0.15302	0.365895
SndEquipDistrWithi	Pearson	0.050126	0.883637
SndEquipDistrWithi	Spearman	0.147844	0.664423
SndEquipDistrFor	Pearson	0.277662	0.408421
SndEquipDistrFor	Spearman	0.288675	0.389283

Table Q79. Statistical Results In Comparison Of Sound Measurements And The Question "I Hear Sounds From Office Equipment In My Work Area" for Building 9.

Variable	Type	Corr	p value
SndEquipHear	Pearson	0.158144	0.231587
SndEquipHear	Spearman	0.07119	0.592094
SndEquipAnnoy	Pearson	-0.25183	0.224601
SndEquipAnnoy	Spearman	-0.21133	0.310546
SndEquipProdAffect	Pearson	-0.08625	0.681843
SndEquipProdAffect	Spearman	0.033996	0.87184
SndEquipDistrWithi	Pearson	0.236395	0.378066
SndEquipDistrWithi	Spearman	0.137079	0.61269
SndEquipDistrFor	Pearson	0.1048	0.699303
SndEquipDistrFor	Spearman	0.136522	0.614148

Table Q80. Statistical Results In Comparison Of Sound Measurements And The Question "I Hear Sounds From Office Equipment In My Work Area" for Building 10.

Variable	Type	Corr	p value
SndEquipHear	Pearson	0.382131	0.000717
SndEquipHear	Spearman	0.417021	0.000198
SndEquipAnnoy	Pearson	-0.04031	0.802425
SndEquipAnnoy	Spearman	-0.18475	0.247535
SndEquipProdAffect	Pearson	-0.01994	0.901508
SndEquipProdAffect	Spearman	-0.07838	0.626183
SndEquipDistrWithi	Pearson	-0.13195	0.601729
SndEquipDistrWithi	Spearman	-0.11602	0.646637
SndEquipDistrFor	Pearson	0.085692	0.735302
SndEquipDistrFor	Spearman	0.096381	0.703619

Q21. Statistical Results In Comparison Of Sound Measurements And The Cause Of The Office Equipment Sound Distraction

(Bldg ID = building identification; Type = statistical analysis performed; Corr = correlation, yellow highlight = significant [p<0.05]; green highlight = moderately significant [0.05<p<0.075]; n/a = not applicable as there were no responses to this question).

Table Q81. Statistical results in comparison of sound measurements and the cause of the office equipment sound distraction for "too loud" and L_90 minus L_10 for NC.

Bldg ID	Type	Corr	P value
1	Pearson	0.711935	0.047593
1	Spearman	0.755291	0.030204
2	Pearson	0.107818	0.818024
2	Spearman	0.104911	0.822876
3	Pearson	0.146143	0.618112
3	Spearman	0.18345	0.530152
4	Pearson	0.166617	0.522729
4	Spearman	0.080695	0.758180
5	Pearson	0.119589	0.605625
5	Spearman	0.092009	0.691617
6	Pearson	-0.27592	0.063444
6	Spearman	-0.33963	0.020933
7	Pearson	0.048776	0.631630
7	Spearman	-0.03688	0.717077
8	Pearson	0.154862	0.333651
8	Spearman	0.153693	0.337359
9	Pearson	-0.17748	0.178687
9	Spearman	-0.12091	0.361656
10	Pearson	0.074811	0.523540
10	Spearman	0.148885	0.202363

Table Q82. Statistical results in comparison of sound measurements and the cause of the office equipment sound distraction for "intermittent/unpredictable" and L_90 minus L_50 for NC.

Bldg ID	Type	Corr	p value
1	Pearson	0.413375	0.308691
1	Spearman	0.433555	0.283209
2	Pearson	0.946149	0.001255
2	Spearman	0.812636	0.026310
3	Pearson	n/a	n/a
3	Spearman	n/a	n/a
4	Pearson	-0.03507	0.893700
4	Spearman	0.152767	0.558313
5	Pearson	0.101180	0.662548
5	Spearman	0.013710	0.952965
6	Pearson	0.329355	0.025412
6	Spearman	0.327780	0.026164
7	Pearson	0.068126	0.502849
7	Spearman	0.091684	0.366758
8	Pearson	-0.15912	0.320358
8	Spearman	-0.16872	0.291658
9	Pearson	-0.04420	0.739605
9	Spearman	-0.10392	0.433449
10	Pearson	0.046692	0.690788
10	Spearman	0.054693	0.641183

Table Q83. Statistical results in comparison of sound measurements and the cause of the office equipment sound distraction for "increases /decreases" and L_80 minus L_50 for NC.

Bldg ID	Type	Corr	p value
1	Pearson	n/a	n/a
1	Spearman	n/a	n/a
2	Pearson	n/a	n/a
2	Spearman	n/a	n/a
3	Pearson	n/a	n/a
3	Spearman	n/a	n/a
4	Pearson	n/a	n/a
4	Spearman	n/a	n/a
5	Pearson	n/a	n/a
5	Spearman	n/a	n/a
6	Pearson	0.218444	0.144713
6	Spearman	0.229186	0.125496
7	Pearson	0.027566	0.786509
7	Spearman	0.095572	0.346699
8	Pearson	-0.16055	0.315981
8	Spearman	-0.15191	0.343061
9	Pearson	0.059652	0.653583
9	Spearman	0.068674	0.605283
10	Pearson	n/a	n/a
10	Spearman	n/a	n/a

Table Q84. Statistical results in comparison of sound measurements and the cause of the office equipment sound distraction for "understandable" and L_80 minus L_50 for NC.

Bldg ID	Type	Corr	p value
1	Pearson	n/a	n/a
1	Spearman	n/a	n/a
2	Pearson	-0.58278	0.169709
2	Spearman	-0.52455	0.226767
3	Pearson	n/a	n/a
3	Spearman	n/a	n/a
4	Pearson	-0.33020	0.195516
4	Spearman	-0.33992	0.181891
5	Pearson	-0.12972	0.575181
5	Spearman	-0.09449	0.683706
6	Pearson	-0.08733	0.563866
6	Spearman	-0.06876	0.649809
7	Pearson	0.108630	0.284486
7	Spearman	0.106225	0.295347
8	Pearson	n/a	n/a
8	Spearman	n/a	n/a
9	Pearson	n/a	n/a
9	Spearman	n/a	n/a
10	Pearson	n/a	n/a
10	Spearman	n/a	n/a

Q22. Statistical Results In Comparison Of Sound Measurements And The Question "I Hear Sounds From Building Mechanical Equipment In My Work Area"

… (SndMechHear) with follow on questions concerning the sound affecting productivity (SndMechProdAffect), if the sound was annoying/distracting (SndMEchAnnoy), and how soon the annoyance/distraction occurred (SndMechDistrWithin) and for how long (SndMechDistrFor) the annoyance/distraction continued

(Bldg ID = building identification; Type = statistical analysis performed; Corr = correlation, yellow highlight = significant [$p<0.05$]; green highlight = moderately significant [$0.05<p<0.075$]; n/a = not applicable as there were no responses to this question).

Table Q85. Statistical Results in Comparison of Sound Measurements and the Question "I Hear Sounds From Building Mechanical Equipment In My Work Area" for Building 1.

Variable	Type	Corr	p value
SndMechHear	Pearson	-0.39044	0.338918
SndMechHear	Spearman	-0.23703	0.571940
SndMechAnnoy	Pearson	0.403542	0.427545
SndMechAnnoy	Spearman	0.750366	0.085697
SndMechProdAffect	Pearson	0.109134	0.836948
SndMechProdAffect	Spearman	0.417786	0.409782
SndMechDistrWithin	Pearson	-0.27735	0.821088
SndMechDistrWithin	Spearman	0	1
SndMechDistrFor	Pearson	-0.69338	0.512246
SndMechDistrFor	Spearman	-0.86603	0.333333

Table Q86. Statistical Results in Comparison of Sound Measurements and the Question "I Hear Sounds From Building Mechanical Equipment In My Work Area" for Building 2.

Variable	Type	Corr	p value
SndMechHear	Pearson	0.645764	0.117185
SndMechHear	Spearman	0.63796	0.123159
SndMechAnnoy	Pearson	0.755929	0.454371
SndMechAnnoy	Spearman	0.866025	0.333333
SndMechProdAffect	Pearson	0.755929	0.454371
SndMechProdAffect	Spearman	0.866025	0.333333
SndMechDistrWithin	Pearson	n/a	n/a
SndMechDistrWithin	Spearman	n/a	n/a
SndMechDistrFor	Pearson	n/a	n/a
SndMechDistrFor	Spearman	n/a	n/a

Table Q87. Statistical Results in Comparison of Sound Measurements and the Question "I Hear Sounds From Building Mechanical Equipment In My Work Area" for Building 3.

Variable	Type	Corr	p value
SndMechHear	Pearson	-0.07125	0.808756
SndMechHear	Spearman	-0.05882	0.841677
SndMechAnnoy	Pearson	-0.08692	0.824045
SndMechAnnoy	Spearman	-0.05507	0.888102
SndMechProdAffect	Pearson	0.263547	0.493219
SndMechProdAffect	Spearman	0.188982	0.626283
SndMechDistrWithin	Pearson	-0.03432	0.956306
SndMechDistrWithin	Spearman	0.186339	0.764126
SndMechDistrFor	Pearson	-0.03432	0.956306
SndMechDistrFor	Spearman	0.186339	0.764126

Table Q88. Statistical Results in Comparison of Sound Measurements and the Question "I Hear Sounds From Building Mechanical Equipment In My Work Area" for Building 4.

Variable	Type	Corr	p value
SndMechHear	Pearson	0.420737	0.092623
SndMechHear	Spearman	0.408156	0.103857
SndMechAnnoy	Pearson	0.214155	0.552437
SndMechAnnoy	Spearman	0.37195	0.289887
SndMechProdAffect	Pearson	-0.25028	0.485540
SndMechProdAffect	Spearman	-0.17484	0.629012
SndMechDistrWithin	Pearson	-0.45579	0.256372
SndMechDistrWithin	Spearman	-0.51952	0.186977
SndMechDistrFor	Pearson	-0.13694	0.746427
SndMechDistrFor	Spearman	-0.06373	0.880836

Table Q89. Statistical Results in Comparison of Sound Measurements and the Question "I Hear Sounds From Building Mechanical Equipment In My Work Area" for Building 5.

Variable	Type	Corr	p value
SndMechHear	Pearson	0.08242	0.722461
SndMechHear	Spearman	0.141895	0.539516
SndMechAnnoy	Pearson	0.5	0.666667
SndMechAnnoy	Spearman	0.5	0.666667
SndMechProdAffect	Pearson	-0.5	0.666667
SndMechProdAffect	Spearman	-0.5	0.666667
SndMechDistrWithin	Pearson	1	
SndMechDistrWithin	Spearman	1	
SndMechDistrFor	Pearson	-1	
SndMechDistrFor	Spearman	-1	

Table Q90. Statistical Results in Comparison of Sound Measurements and the Question "I Hear Sounds From Building Mechanical Equipment In My Work Area" for Building 6.

Variable	Type	Corr	p value
SndMechHear	Pearson	-0.07441	0.623112
SndMechHear	Spearman	-0.2853	0.054622
SndMechAnnoy	Pearson	-0.08453	0.694534
SndMechAnnoy	Spearman	-0.24456	0.249424
SndMechProdAffect	Pearson	0.062249	0.772615
SndMechProdAffect	Spearman	0.031035	0.885536
SndMechDistrWithin	Pearson	-0.47319	0.087462
SndMechDistrWithin	Spearman	-0.29736	0.301849
SndMechDistrFor	Pearson	-0.17292	0.554405
SndMechDistrFor	Spearman	-0.08886	0.762584

Table Q91. Statistical Results in Comparison of Sound Measurements and the Question "I Hear Sounds From Building Mechanical Equipment In My Work Area" for Building 7.

Variable	Type	Corr	p value
SndMechHear	Pearson	0.26055	0.009196
SndMechHear	Spearman	0.232596	0.020516
SndMechAnnoy	Pearson	0.124122	0.411159
SndMechAnnoy	Spearman	0.034143	0.821774
SndMechProdAffect	Pearson	0.199669	0.178432
SndMechProdAffect	Spearman	0.111256	0.456566
SndMechDistrWithin	Pearson	-0.11714	0.603666
SndMechDistrWithin	Spearman	-0.18956	0.398169
SndMechDistrFor	Pearson	0.2476	0.266582
SndMechDistrFor	Spearman	0.165579	0.461484

Table Q92. Statistical Results in Comparison of Sound Measurements and the Question "I Hear Sounds From Building Mechanical Equipment In My Work Area" for Building 8.

Variable	Type	Corr	p value
SndMechHear	Pearson	-0.19222	0.228590
SndMechHear	Spearman	-0.20602	0.196266
SndMechAnnoy	Pearson	0.057599	0.892241
SndMechAnnoy	Spearman	0	1
SndMechProdAffect	Pearson	-0.15785	0.708913
SndMechProdAffect	Spearman	-0.42524	0.293576
SndMechDistrWithin	Pearson	0.927019	0.244724
SndMechDistrWithin	Spearman	1	0
SndMechDistrFor	Pearson	0.890361	0.300904
SndMechDistrFor	Spearman	0.5	0.666667

Table Q93. Statistical Results in Comparison of Sound Measurements and the Question "I Hear Sounds From Building Mechanical Equipment In My Work Area" for Building 9.

Variable	Type	Corr	p value
SndMechHear	Pearson	-0.33454	0.009604
SndMechHear	Spearman	-0.40015	0.001688
SndMechAnnoy	Pearson	0.298698	0.176918
SndMechAnnoy	Spearman	0.410143	0.057983
SndMechProdAffect	Pearson	0.244244	0.273328
SndMechProdAffect	Spearman	0.269326	0.225487
SndMechDistrWithin	Pearson	-0.24768	0.393243
SndMechDistrWithin	Spearman	-0.42429	0.130525
SndMechDistrFor	Pearson	-0.16746	0.567163
SndMechDistrFor	Spearman	-0.24445	0.399639

Table Q94. Statistical Results in Comparison of Sound Measurements and the Question "I Hear Sounds From Building Mechanical Equipment In My Work Area" for Building 10.

Variable	Type	Corr	p value
SndMechHear	Pearson	0.16175	0.165621
SndMechHear	Spearman	0.178565	0.125326
SndMechAnnoy	Pearson	0.029202	0.859922
SndMechAnnoy	Spearman	-0.07268	0.660156
SndMechProdAffect	Pearson	0.082061	0.619447
SndMechProdAffect	Spearman	-0.06468	0.695669
SndMechDistrWithin	Pearson	-0.04984	0.808927
SndMechDistrWithin	Spearman	0.025555	0.901380
SndMechDistrFor	Pearson	0.385494	0.051788
SndMechDistrFor	Spearman	0.282503	0.162017

Q23. Statistical Results in Comparison of Sound Measurements and the Cause of the Mechanical Equipment Sound Distraction

(Bldg ID = building identification; Type = statistical analysis performed; Corr = correlation, yellow highlight = significant [p<0.05]; green highlight = moderately significant [0.05<p<0.075]; n/a = not applicable as there were no responses to this question).

Table Q95. Statistical Results in Comparison of Sound Measurements and the Cause of the Mechanical Equipment Sound Distraction for "too loud."

Bldg ID	Type	Corr	p value
1	Pearson	0.160814	0.703632
1	Spearman	0.389742	0.339863
2	Pearson	n/a	n/a
2	Spearman	n/a	n/a
3	Pearson	n/a	n/a
3	Spearman	n/a	n/a
4	Pearson	0.638476	0.005808
4	Spearman	0.553614	0.021136
5	Pearson	0.046898	0.840023
5	Spearman	-0.01890	0.935198
6	Pearson	0.335497	0.022647
6	Spearman	0.334936	0.022889
7	Pearson	0.018193	0.858150
7	Spearman	0.010156	0.920524
8	Pearson	-0.00199	0.990144
8	Spearman	-0.07362	0.647341
9	Pearson	-0.06383	0.630998
9	Spearman	0.011557	0.930772
10	Pearson	-0.07748	0.508764
10	Spearman	-0.02345	0.841725

Table Q96. Statistical Results in Comparison of Sound Measurements and the Cause of the Mechanical Equipment Sound Distraction for "intermittent/unpredictable."

Bldg ID	Type	Corr	p value
1	Pearson	n/a	n/a
1	Spearman	n/a	n/a
2	Pearson	0.654872	0.110406
2	Spearman	0.812636	0.026310
3	Pearson	0.06472	0.826017
3	Spearman	0.083666	0.776134
4	Pearson	-0.28567	0.266348
4	Spearman	-0.36282	0.152338
5	Pearson	0.154991	0.502323
5	Spearman	0.188982	0.411972
6	Pearson	-0.18281	0.223976
6	Spearman	-0.19289	0.199019
7	Pearson	-0.04522	0.656734
7	Spearman	-0.01408	0.890017
8	Pearson	n/a	n/a
8	Spearman	n/a	n/a
9	Pearson	0.042951	0.746695
9	Spearman	0.050496	0.704088
10	Pearson	-0.03477	0.767108
10	Spearman	-0.03384	0.773167

Table Q97. Statistical Results in Comparison of Sound Measurements and the Cause of the Mechanical Equipment Sound Distraction for "increases /decreases."

Bldg ID	Type	Corr	p value
1	Pearson	0.186645	0.658083
1	Spearman	0.085049	0.841301
2	Pearson	n/a	n/a
2	Spearman	n/a	n/a
3	Pearson	n/a	n/a
3	Spearman	n/a	n/a
4	Pearson	0.252997	0.382829
4	Spearman	0.25683	0.375414
5	Pearson	n/a	n/a
5	Spearman	n/a	n/a
6	Pearson	-0.24742	0.097359
6	Spearman	-0.37225	0.010850
7	Pearson	0.219895	0.028744
7	Spearman	0.190666	0.058706
8	Pearson	n/a	n/a
8	Spearman	n/a	n/a
9	Pearson	-0.08534	0.520441
9	Spearman	-0.08261	0.533927
10	Pearson	n/a	n/a
10	Spearman	n/a	n/a

Table Q98. Statistical Results in Comparison of Sound Measurements and the Cause of the Mechanical Equipment Sound Distraction for "understandable."

Bldg ID	Type	Corr	p value
1	Pearson	n/a	n/a
1	Spearman	n/a	n/a
2	Pearson	n/a	n/a
2	Spearman	n/a	n/a
3	Pearson	n/a	n/a
3	Spearman	n/a	n/a
4	Pearson	n/a	n/a
4	Spearman	n/a	n/a
5	Pearson	n/a	n/a
5	Spearman	n/a	n/a
6	Pearson	n/a	n/a
6	Spearman	n/a	n/a
7	Pearson	-0.02286	0.822302
7	Spearman	-0.03327	0.743726
8	Pearson	n/a	n/a
8	Spearman	n/a	n/a
9	Pearson	n/a	n/a
9	Spearman	n/a	n/a
10	Pearson	0.089607	0.444556
10	Spearman	0.098130	0.402264

Q24. Statistical Results in Comparison of Sound Measurements and the Question "I Hear Sounds From Air Diffuser/Air Supply In My Work Area"

… (SndAirHear) with follow on questions concerning the sound affecting productivity (SndAirProdAffect), if the sound was annoying/distracting (SndAirAnnoy), and how soon the annoyance/distraction occurred (SndAirDistrWithin) and for how long (SndAirDistrFor) the annoyance/distraction continued

(Bldg ID = building identification; Type = statistical analysis performed; Corr = correlation, yellow highlight = significant [$p<0.05$]; green highlight = moderately significant [$0.05<p<0.075$]; n/a = not applicable as there were no responses to this question).

Table Q99. Statistical Results in Comparison of Sound Measurements and the Question "I Hear Sounds From Air Diffuser/Air Supply In My Work Area" for Building 1.

Variable	Type	Corr	p value
SndAirHear	Pearson	-0.48089	0.227695
SndAirHear	Spearman	-0.39491	0.332923
SndAirAnnoy	Pearson	0.507754	0.303822
SndAirAnnoy	Spearman	0.750366	0.085697
SndAirProdAffect	Pearson	0.225675	0.667234
SndAirProdAffect	Spearman	0.417786	0.409782
SndAirDistrWithin	Pearson	-0.27735	0.821088
SndAirDistrWithin	Spearman	0	1
SndAirDistrFor	Pearson	-0.18898	0.878962
SndAirDistrFor	Spearman	0	1

Table Q100. Statistical Results in Comparison of Sound Measurements and the Question "I Hear Sounds From Air Diffuser/Air Supply In My Work Area" for Building 2.

Variable	Type	Corr	p value
SndAirHear	Pearson	0.807769	0.027974
SndAirHear	Spearman	0.563104	0.188095
SndAirAnnoy	Pearson	0.755929	0.454371
SndAirAnnoy	Spearman	0.866025	0.333333
SndAirProdAffect	Pearson	0.5	0.666667
SndAirProdAffect	Spearman	0.5	0.666667
SndAirDistrWithin	Pearson	n/a	n/a
SndAirDistrWithin	Spearman	n/a	n/a
SndAirDistrFor	Pearson	n/a	n/a
SndAirDistrFor	Spearman	n/a	n/a

Table Q101. Statistical Results in Comparison of Sound Measurements and the Question "I Hear Sounds From Air Diffuser/Air Supply In My Work Area" for Building 3.

Variable	Type	Corr	p value
SndAirHear	Pearson	-0.30211	0.293823
SndAirHear	Spearman	0.007293	0.980259
SndAirAnnoy	Pearson	-0.26265	0.409510
SndAirAnnoy	Spearman	-0.1824	0.570446
SndAirProdAffect	Pearson	-0.13443	0.677014
SndAirProdAffect	Spearman	0.137335	0.670384
SndAirDistrWithin	Pearson	0.210042	0.734546
SndAirDistrWithin	Spearman	0	1
SndAirDistrFor	Pearson	0.722222	0.168229
SndAirDistrFor	Spearman	0.740436	0.152413

Table Q102. Statistical Results in Comparison of Sound Measurements and the Question "I Hear Sounds From Air Diffuser/Air Supply In My Work Area" for Building 4.

Variable	Type	Corr	p value
SndAirHear	Pearson	0.227246	0.380406
SndAirHear	Spearman	0.17218	0.508737
SndAirAnnoy	Pearson	0.374578	0.186990
SndAirAnnoy	Spearman	0.286203	0.321203
SndAirProdAffect	Pearson	0.227141	0.434839
SndAirProdAffect	Spearman	0.256022	0.376971
SndAirDistrWithin	Pearson	-0.62514	0.133299
SndAirDistrWithin	Spearman	-0.68885	0.086971
SndAirDistrFor	Pearson	-0.06026	0.897891
SndAirDistrFor	Spearman	-0.10784	0.817983

Table Q103. Statistical Results in Comparison of Sound Measurements and the Question "I Hear Sounds From Air Diffuser/Air Supply In My Work Area" for Building 5.

Variable	Type	Corr	p value
SndAirHear	Pearson	-0.15536	0.501286
SndAirHear	Spearman	0.001192	0.995908
SndAirAnnoy	Pearson	-0.58265	0.169827
SndAirAnnoy	Spearman	-0.72457	0.065494
SndAirProdAffect	Pearson	-0.1913	0.681152
SndAirProdAffect	Spearman	-0.3118	0.496016
SndAirDistrWithin	Pearson	-1	
SndAirDistrWithin	Spearman	-1	
SndAirDistrFor	Pearson	-1	
SndAirDistrFor	Spearman	-1	

Table Q104. Statistical Results in Comparison of Sound Measurements and the Question "I Hear Sounds From Air Diffuser/Air Supply In My Work Area" for Building 6.

Variable	Type	Corr	p value
SndAirHear	Pearson	-0.03939	0.794960
SndAirHear	Spearman	-0.05968	0.693595
SndAirAnnoy	Pearson	-0.43789	0.022347
SndAirAnnoy	Spearman	-0.34233	0.080485
SndAirProdAffect	Pearson	-0.21964	0.270994
SndAirProdAffect	Spearman	-0.06634	0.742335
SndAirDistrWithin	Pearson	-0.19375	0.506881
SndAirDistrWithin	Spearman	-0.07603	0.796156
SndAirDistrFor	Pearson	0.050203	0.864667
SndAirDistrFor	Spearman	-0.02115	0.942790

Table Q105. Statistical Results in Comparison of Sound Measurements and the Question "I Hear Sounds From Air Diffuser/Air Supply In My Work Area" for Building 7.

Variable	Type	Corr	p value
SndAirHear	Pearson	0.060341	0.552980
SndAirHear	Spearman	0.126698	0.211424
SndAirAnnoy	Pearson	-0.01155	0.919527
SndAirAnnoy	Spearman	0.010965	0.923593
SndAirProdAffect	Pearson	-0.05457	0.635135
SndAirProdAffect	Spearman	-0.12944	0.258702
SndAirDistrWithin	Pearson	0.244803	0.162902
SndAirDistrWithin	Spearman	0.290637	0.095411
SndAirDistrFor	Pearson	0.306384	0.078010
SndAirDistrFor	Spearman	0.361194	0.035837

Table Q106. Statistical Results in Comparison of Sound Measurements and the Question "I Hear Sounds From Air Diffuser/Air Supply In My Work Area" for Building 8.

Variable	Type	Corr	p value
SndAirHear	Pearson	0.095069	0.554349
SndAirHear	Spearman	0.146682	0.360117
SndAirAnnoy	Pearson	-0.36332	0.272087
SndAirAnnoy	Spearman	-0.42204	0.196022
SndAirProdAffect	Pearson	n/a	n/a
SndAirProdAffect	Spearman	n/a	n/a
SndAirDistrWithin	Pearson	n/a	n/a
SndAirDistrWithin	Spearman	n/a	n/a
SndAirDistrFor	Pearson	-1	0
SndAirDistrFor	Spearman	-1	0

Table Q107. Statistical Results in Comparison of Sound Measurements and the Question "I Hear Sounds From Air Diffuser/Air Supply In My Work Area" for Building 9.

Variable	Type	Corr	p value
SndAirHear	Pearson	-0.13724	0.299945
SndAirHear	Spearman	-0.25039	0.055787
SndAirAnnoy	Pearson	-0.36490	0.094962
SndAirAnnoy	Spearman	-0.10430	0.644148
SndAirProdAffect	Pearson	-0.15603	0.488064
SndAirProdAffect	Spearman	0	1
SndAirDistrWithin	Pearson	-0.40080	0.221864
SndAirDistrWithin	Spearman	-0.43781	0.178062
SndAirDistrFor	Pearson	0.113938	0.753971
SndAirDistrFor	Spearman	0.167162	0.644381

Table Q108. Statistical Results in Comparison of Sound Measurements and the Question "I Hear Sounds From Air Diffuser/Air Supply In My Work Area" for Building 10.

Variable	Type	Corr	p value
SndAirHear	Pearson	-0.11287	0.334990
SndAirHear	Spearman	-0.13795	0.237907
SndAirAnnoy	Pearson	0.011175	0.926847
SndAirAnnoy	Spearman	-0.03200	0.792589
SndAirProdAffect	Pearson	0.017889	0.883140
SndAirProdAffect	Spearman	0.017696	0.884396
SndAirDistrWithin	Pearson	0.077735	0.615985
SndAirDistrWithin	Spearman	0.142590	0.355832
SndAirDistrFor	Pearson	0.494135	0.000652
SndAirDistrFor	Spearman	0.491961	0.000694

Q25. Statistical Results in Comparison of Sound Measurements and the Cause of the Air Diffuser/Air Supply Sound Distraction

(Bldg ID = building identification; Type = statistical analysis performed; Corr = correlation, yellow highlight = significant [p<0.05]; green highlight = moderately significant [0.05<p<0.075]; n/a = not applicable as there were no responses to this question).

Table Q109. Statistical Results in Comparison of Sound Measurements and the Cause of the Air Diffuser/Air Supply Sound Distraction for "too loud."

Bldg ID	Type	Corr	p value
1	Pearson	0.136366	0.747465
1	Spearman	0.425243	0.293576
2	Pearson	0.633148	0.126919
2	Spearman	0.524554	0.226767
3	Pearson	-0.03768	0.898243
3	Spearman	0.216025	0.458234
4	Pearson	0.531153	0.028237
4	Spearman	0.500306	0.040826
5	Pearson	-0.03223	0.889685
5	Spearman	-0.0189	0.935198
6	Pearson	-0.32213	0.029019
6	Spearman	-0.29261	0.048455
7	Pearson	0.097102	0.339002
7	Spearman	0.091024	0.370235
8	Pearson	n/a	n/a
8	Spearman	n/a	n/a
9	Pearson	-0.18237	0.166824
9	Spearman	-0.20571	0.118037
16	Pearson	-0.18387	0.114317
10	Spearman	-0.14627	0.210503

Table Q110. Statistical Results in Comparison of Sound Measurements and the Cause of the Air Diffuser/Air Supply Sound Distraction for "intermittent/unpredictable."

Bldg ID	Type	Corr	p value
1	Pearson	-0.04522	0.915322
1	Spearman	0.129914	0.759138
2	Pearson	n/a	n/a
2	Spearman	n/a	n/a
3	Pearson	-0.09533	0.745798
3	Spearman	0.11007	0.707967
4	Pearson	-0.37334	0.139925
4	Spearman	-0.33892	0.183273
5	Pearson	-0.26114	0.252867
5	Spearman	-0.32127	0.155588
6	Pearson	-0.03687	0.807790
6	Spearman	-0.00338	0.982193
7	Pearson	-0.11075	0.275131
7	Spearman	-0.10112	0.319288
8	Pearson	-0.00248	0.987715
8	Spearman	0.103575	0.519297
9	Pearson	-0.16941	0.199605
9	Spearman	-0.25253	0.053653
10	Pearson	-0.01249	0.915297
10	Spearman	-0.00322	0.978097

Table Q111. Statistical Results in Comparison of Sound Measurements and the Cause of the Air Diffuser/Air Supply Sound Distraction of "increases/decreases."

Bldg ID	Type	Corr	p value
1	Pearson	n/a	n/a
1	Spearman	n/a	n/a
2	Pearson	n/a	n/a
2	Spearman	n/a	n/a
3	Pearson	-0.06357	0.829062
3	Spearman	0.14676	0.616615
4	Pearson	n/a	n/a
4	Spearman	n/a	n/a
5	Pearson	n/a	n/a
5	Spearman	n/a	n/a
6	Pearson	n/a	n/a
6	Spearman	n/a	n/a
7	Pearson	0.234835	0.019298
7	Spearman	0.190666	0.058706
8	Pearson	-0.0371	0.817857
8	Spearman	0	1
9	Pearson	-0.14631	0.268831
9	Spearman	-0.11785	0.374035
10	Pearson	-0.18941	0.103622
10	Spearman	-0.20582	0.076477

Table Q112. Statistical Results in Comparison of Sound Measurements and the Cause of the Air Diffuser/Air Supply Sound Distraction for "understandable."

Bldg ID	Type	Corr	p value
1	Pearson	n/a	n/a
1	Spearman	n/a	n/a
2	Pearson	0.613131	0.143175
2	Spearman	0.524554	0.226767
3	Pearson	n/a	n/a
3	Spearman	n/a	n/a
4	Pearson	n/a	n/a
4	Spearman	n/a	n/a
5	Pearson	n/a	n/a
5	Spearman	n/a	n/a
6	Pearson	n/a	n/a
6	Spearman	n/a	n/a
7	Pearson	n/a	n/a
7	Spearman	n/a	n/a
8	Pearson	n/a	n/a
8	Spearman	n/a	n/a
9	Pearson	n/a	n/a
9	Spearman	n/a	n/a
10	Pearson	n/a	n/a
10	Spearman	n/a	n/a

Q26. Statistical Results in Comparison of Sound Measurements and the Question Of Privacy

… (SndPrivLevel) with follow on questions concerning privacy to have a conversation (SndPrivConv) with follow on questions concerning postponing a conversation until later (SndPrivConvLater), leaving the are to gain privacy (SndPrivConvLeave) and having privacy to have a telephone conversation (SndPrivTel), postponing a telephone conversation until later (SndPrivTelLater),and leaving the are to gain privacy for a telephone conversation (SndPrivTelLeave)

(Bldg ID = building identification; Type = statistical analysis performed; Corr = correlation, yellow highlight = significant [$p<0.05$]; green highlight = moderately significant [$0.05<p<0.075$]; n/a = not applicable as there were no responses to this question).

Table Q113. Statistical Results in Comparison of Sound Measurements and the Question Of Privacy for Building 1.

Variable	Type	Corr	p value
SndPrivLevel	Pearson	0.328148	0.427464
SndPrivLevel	Spearman	0.175014	0.678489
SndPrivConv	Pearson	-0.16535	0.723120
SndPrivConv	Spearman	-0.37507	0.407088
SndPrivConvLater	Pearson	0.212542	0.647272
SndPrivConvLater	Spearman	0.233021	0.615064
SndPrivConvLeave	Pearson	-0.41828	0.350358
SndPrivConvLeave	Spearman	-0.12502	0.789409
SndPrivTel	Pearson	-0.16535	0.723120
SndPrivTel	Spearman	-0.37507	0.407088
SndPrivTelLater	Pearson	-0.13976	0.765054
SndPrivTelLater	Spearman	0.098039	0.834362
SndPrivTelLeave	Pearson	-0.30626	0.504119
SndPrivTelLeave	Spearman	0	1

Table Q114. Statistical Results in Comparison of Sound Measurements and the Question Of Privacy for Building 2.

Variable	Type	Corr	p value
SndPrivLevel	Pearson	-0.00176	0.997011
SndPrivLevel	Spearman	0.115406	0.805383
SndPrivConv	Pearson	-0.01399	0.979019
SndPrivConv	Spearman	0	1
SndPrivConvLater	Pearson	-0.38507	0.450944
SndPrivConvLater	Spearman	-0.39728	0.435437
SndPrivConvLeave	Pearson	0.24328	0.642279
SndPrivConvLeave	Spearman	0.318182	0.538834
SndPrivTel	Pearson	-0.01399	0.979019
SndPrivTel	Spearman	0	1
SndPrivTelLater	Pearson	-0.31907	0.537636
SndPrivTelLater	Spearman	-0.25426	0.626833
SndPrivTelLeave	Pearson	-0.13082	0.804885
SndPrivTelLeave	Spearman	-0.12713	0.810335

Q115. Statistical Results in Comparison of Sound Measurements and the Question Of Privacy for Building 3.

Variable	Type	Corr	p value
SndPrivLevel	Pearson	0.409317	0.146135
SndPrivLevel	Spearman	0.159729	0.585443
SndPrivConv	Pearson	0.428574	0.143969
SndPrivConv	Spearman	0.230685	0.448298
SndPrivConvLater	Pearson	0.235605	0.438401
SndPrivConvLater	Spearman	0.200928	0.510395
SndPrivConvLeave	Pearson	0.092103	0.764743
SndPrivConvLeave	Spearman	-0.03349	0.913514
SndPrivTel	Pearson	0.460148	0.113604
SndPrivTel	Spearman	0.306028	0.309206
SndPrivTelLater	Pearson	0.311579	0.300058
SndPrivTelLater	Spearman	0.341489	0.253477
SndPrivTelLeave	Pearson	-0.10342	0.736718
SndPrivTelLeave	Spearman	-0.25988	0.391190

Table Q116. Statistical Results in Comparison of Sound Measurements and the Question Of Privacy for Building 4.

Variable	Type	Corr	p value
SndPrivLevel	Pearson	0.064150	0.806764
SndPrivLevel	Spearman	0.047624	0.855973
SndPrivConv	Pearson	0.011410	0.969120
SndPrivConv	Spearman	-0.0529	0.857464
SndPrivConvLater	Pearson	0.102503	0.727320
SndPrivConvLater	Spearman	0.054717	0.852617
SndPrivConvLeave	Pearson	-0.37012	0.192714
SndPrivConvLeave	Spearman	-0.36545	0.198821
SndPrivTel	Pearson	0.011410	0.969120
SndPrivTel	Spearman	-0.0529	0.857464
SndPrivTelLater	Pearson	0.067788	0.817895
SndPrivTelLater	Spearman	0.059033	0.841119
SndPrivTelLeave	Pearson	-0.33593	0.240293
SndPrivTelLeave	Spearman	-0.32522	0.256542

Table Q117. Statistical Results in Comparison of Sound Measurements and the Question Of Privacy for Building 5.

Variable	Type	Corr	p value
SndPrivLevel	Pearson	-0.13251	0.566920
SndPrivLevel	Spearman	0.00035	0.998799
SndPrivConv	Pearson	0.09362	0.694625
SndPrivConv	Spearman	0.138858	0.559322
SndPrivConvLater	Pearson	0.044899	0.864138
SndPrivConvLater	Spearman	0.01292	0.960747
SndPrivConvLeave	Pearson	-0.10646	0.684242
SndPrivConvLeave	Spearman	-0.19057	0.463764
SndPrivTel	Pearson	0.109857	0.644756
SndPrivTel	Spearman	0.197884	0.402986
SndPrivTelLater	Pearson	0.041974	0.868653
SndPrivTelLater	Spearman	-0.00782	0.975424
SndPrivTelLeave	Pearson	-0.10523	0.677727
SndPrivTelLeave	Spearman	-0.24973	0.317596

Table Q118. Statistical Results in Comparison of Sound Measurements and the Question Of Privacy for Building 6.

Variable	Type	Corr	p value
SndPrivLevel	Pearson	-0.26109	0.079664
SndPrivLevel	Spearman	-0.21363	0.154004
SndPrivConv	Pearson	0.205181	0.237041
SndPrivConv	Spearman	0.233396	0.177220
SndPrivConvLater	Pearson	0.077587	0.667803
SndPrivConvLater	Spearman	-0.01689	0.925659
SndPrivConvLeave	Pearson	-0.11394	0.527807
SndPrivConvLeave	Spearman	-0.1346	0.455162
SndPrivTel	Pearson	0.097924	0.581660
SndPrivTel	Spearman	0.092123	0.604336
SndPrivTelLater	Pearson	0.027167	0.876889
SndPrivTelLater	Spearman	-0.06612	0.705908
SndPrivTelLeave	Pearson	-0.05786	0.741305
SndPrivTelLeave	Spearman	-0.06435	0.713440

Table Q119. Statistical Results in Comparison of Sound Measurements and the Question Of Privacy for Building 7.

Variable	Type	Corr	p value
SndPrivLevel	Pearson	-0.10217	0.314274
SndPrivLevel	Spearman	-0.11596	0.253028
SndPrivConv	Pearson	-0.10261	0.347149
SndPrivConv	Spearman	-0.10782	0.323106
SndPrivConvLater	Pearson	0.033731	0.764984
SndPrivConvLater	Spearman	0.014141	0.900291
SndPrivConvLeave	Pearson	0.036713	0.744883
SndPrivConvLeave	Spearman	0.046369	0.681032
SndPrivTel	Pearson	-0.0674	0.537496
SndPrivTel	Spearman	-0.07348	0.501335
SndPrivTelLater	Pearson	0.164269	0.140287
SndPrivTelLater	Spearman	0.116561	0.297011
SndPrivTelLeave	Pearson	0.066244	0.554317
SndPrivTelLeave	Spearman	0.020497	0.854970

Table Q120. Statistical Results in Comparison of Sound Measurements and the Question Of Privacy for Building 8.

Variable	Type	Corr	p value
SndPrivLevel	Pearson	-0.11745	0.464571
SndPrivLevel	Spearman	-0.26127	0.098947
SndPrivConv	Pearson	0.206942	0.225897
SndPrivConv	Spearman	-0.06867	0.690684
SndPrivConvLater	Pearson	-0.35037	0.039069
SndPrivConvLater	Spearman	-0.33175	0.051546
SndPrivConvLeave	Pearson	0.399833	0.017324
SndPrivConvLeave	Spearman	0.18203	0.295299
SndPrivTel	Pearson	0.301929	0.073507
SndPrivTel	Spearman	0.05288	0.759379
SndPrivTelLater	Pearson	-0.57305	0.000321
SndPrivTelLater	Spearman	-0.48441	0.003190
SndPrivTelLeave	Pearson	0.386272	0.021906
SndPrivTelLeave	Spearman	0.275742	0.108863

Table Q121. Statistical Results in Comparison of Sound Measurements and the Question Of Privacy for Building 9.

Variable	Type	Corr	p value
SndPrivLevel	Pearson	-0.04775	0.719489
SndPrivLevel	Spearman	-0.08409	0.526618
SndPrivConv	Pearson	-0.14869	0.274081
SndPrivConv	Spearman	-0.16085	0.236310
SndPrivConvLater	Pearson	-0.08473	0.542418
SndPrivConvLater	Spearman	-0.09749	0.483100
SndPrivConvLeave	Pearson	0.152198	0.271914
SndPrivConvLeave	Spearman	0.143429	0.300819
SndPrivTel	Pearson	-0.0843	0.536783
SndPrivTel	Spearman	-0.07689	0.573262
SndPrivTelLater	Pearson	-0.02002	0.885739
SndPrivTelLater	Spearman	-0.03527	0.800142
SndPrivTelLeave	Pearson	0.1016	0.464760
SndPrivTelLeave	Spearman	0.091456	0.510721

Table Q122. Statistical Results in Comparison of Sound Measurements and the Question Of Privacy for Building 10.

Variable	Type	Corr	p value
SndPrivLevel	Pearson	0.180573	0.121066
SndPrivLevel	Spearman	0.199116	0.086781
SndPrivConv	Pearson	0.007445	0.951587
SndPrivConv	Spearman	0.012370	0.919645
SndPrivConvLater	Pearson	-0.07441	0.555798
SndPrivConvLater	Spearman	-0.06323	0.616780
SndPrivConvLeave	Pearson	-0.20732	0.097499
SndPrivConvLeave	Spearman	-0.18939	0.130790
SndPrivTel	Pearson	0.085310	0.485823
SndPrivTel	Spearman	0.089258	0.465793
SndPrivTelLater	Pearson	0.020859	0.869001
SndPrivTelLater	Spearman	0.015418	0.902976
SndPrivTelLeave	Pearson	-0.21229	0.089558
SndPrivTelLeave	Spearman	-0.22089	0.077020

Q27. Cumulative Probability Data

Sound level data were compiled in the commonly used metrics listed in Section 3. Cumulative probability levels of that data, without the descriptors, were created so that manageable data tables were available for the correlation analysis.

Table Q123. Cumulative probability sound level by building

Metric	Building ID									
	1	2	3	4	5	6	7	8	9	10
L_99_dBA	62.4	60.1	54.0	62.1	57.0	61.0	62.5	58.7	61.0	58.2
L_95_dBA	57.7	56.0	49.3	55.7	52.0	53.5	54.8	53.7	57.1	54.2
L_90_dBA	54.0	54.0	48.1	53.0	48.9	50.3	52.7	51.3	54.9	52.6
L_80_dBA	49.8	51.0	47.1	49.9	45.7	47.6	51.2	48.4	53.1	51.3
L_50_dBA	47.7	48.5	44.8	45.7	40.4	45.1	47.5	42.9	50.8	48.8
L_33_dBA	46.5	45.6	42.9	44.2	38.2	44.1	46.3	40.1	49.7	47.3
L_10_dBA	45.0	43.9	40.9	40.8	35.5	42.6	44.2	36.9	48.3	44.9
L_5_dBA	44.3	43.4	40.5	39.7	34.5	42.2	43.2	34.3	47.8	43.7
L_99_dBC	69.2	70.3	69.2	68.5	67.9	67.4	72.1	69.9	68.3	68.4
L_95_dBC	68.0	69.2	68.8	66.7	64.5	65.3	69.9	67.7	66.0	67.5
L_90_dBC	67.5	68.4	68.5	66.0	63.7	64.7	68.4	66.8	65.2	66.9
L_80_dBC	66.5	67.0	68.2	65.0	62.9	62.3	67.0	64.9	64.1	66.1
L_50_dBC	64.7	65.6	65.3	62.8	61.2	58.8	63.8	57.7	61.8	61.3
L_33_dBC	64.2	64.9	61.4	61.9	60.1	57.6	63.3	55.9	60.9	59.3
L_10_dBC	62.8	63.1	59.0	60.3	57.1	56.0	62.3	51.3	59.0	56.5
L_5_dBC	62.0	62.6	58.6	59.6	55.8	55.4	62.0	40.4	58.3	55.5
L_99_dBC_dBA	20.7	22.8	24.5	23.6	29.5	22.5	22.3	29.7	16.0	20.5
L_95_dBC_dBA	19.8	21.7	23.9	22.0	27.7	20.4	21.3	27.4	14.1	18.4
L_90_dBC_dBA	19.2	21.0	23.4	21.3	26.1	18.7	20.6	25.7	13.4	17.3
L_80_dBC_dBA	18.6	20.1	22.7	20.1	24.4	16.7	19.6	22.7	12.5	16.1

L_50_dBC_dBA	16.9	17.6	19.5	17.1	20.1	13.3	16.8	13.7	11.0	12.9
L_33_dBC_dBA	16.3	16.3	18.3	15.3	16.8	12.2	15.2	10.0	10.1	11.2
L_10_dBC_dBA	12.5	12.7	15.4	10.6	12.1	9.0	11.8	3.7	7.4	8.1
L_5_dBC_dBA	9.6	10.3	13.6	8.5	10.0	7.0	10.4	3.5	6.0	6.6
L_99_NCMax	59.0	56.9	50.2	59.1	53.3	58.2	58.4	55.0	57.7	54.2
L_95_NCMax	53.6	51.8	45.5	52.0	48.2	49.5	50.7	49.5	52.9	49.8
L_90_NCMax	49.6	49.7	44.6	49.0	44.4	45.9	48.4	46.8	50.6	48.2
L_80_NCMax	46.3	46.5	43.6	46.0	40.5	44.3	46.8	43.3	48.6	46.8
L_50_NCMax	44.6	43.3	39.8	40.0	34.6	40.3	42.0	37.0	46.6	43.4
L_33_NCMax	41.8	40.8	36.9	38.4	31.5	38.9	40.4	33.4	44.7	41.6
L_10_NCMax	39.8	38.9	34.7	34.3	27.8	36.0	37.7	29.9	43.7	39.0
L_5_NCMax	39.4	38.3	33.8	33.0	26.5	35.6	36.4	27.2	43.3	37.6
L_99_RC	57.4	54.4	47.8	56.7	51.4	54.8	56.9	53.3	55.6	52.8
L_95_RC	52.6	50.4	42.6	50.0	46.4	47.6	49.3	48.4	51.7	49.0
L_90_RC	48.2	48.3	40.8	47.3	43.2	44.3	47.2	45.9	49.4	47.5
L_80_RC	42.4	45.0	39.1	44.3	39.8	41.1	45.7	42.9	47.2	46.1
L_50_RC	39.1	42.1	36.6	39.6	34.4	37.3	40.5	36.9	44.3	43.5
L_33_RC	38.0	37.7	35.3	37.8	31.7	36.2	39.2	33.6	43.0	42.0
L_10_RC	34.2	34.5	31.6	33.1	27.4	34.8	36.3	29.5	41.1	39.4
L_5_RC	33.1	33.8	29.3	31.7	25.8	33.9	35.4	27.2	40.4	38.0
L_99_SIL	55.2	52.5	45.7	54.3	49.8	52.8	55.6	51.3	53.3	50.7
L_95_SIL	50.3	48.4	40.1	47.7	44.5	45.2	46.7	46.5	49.3	47.0
L_90_SIL	46.1	46.1	38.3	45.0	41.4	41.9	44.8	44.1	47.1	45.6
L_80_SIL	40.2	42.8	36.6	42.1	38.1	38.8	43.4	41.3	44.9	44.2
L_50_SIL	36.7	39.7	34.0	37.3	32.5	34.9	38.5	35.5	41.6	41.7
L_33_SIL	35.5	35.3	32.8	35.3	29.9	33.9	37.1	32.1	40.2	40.2
L_10_SIL	31.5	32.2	29.3	30.6	25.9	32.1	34.3	28.0	38.0	37.6
L_5_SIL	30.3	31.5	27.1	29.0	24.2	31.2	33.3	25.7	37.2	36.3

APPENDIX R- DESCRIPTION OF LIGHTING SYSTEMS

Table R1. Descriptions of Ten Office Buildings and Lighting Systems

Building ID.	Office Setup	Ambient Lighting			Task Lighting		LEED Certified
		System Type	Mounting Height (m)	Light Source	System Type	Light Source	
1	Cubicles	Direct	2.63 and 3.04	T8, 4ft, 32w, 3375K, CRI75	Furniture integrated	T8, 17~32w, 3184K, CRI81	No
2	Cubicles	Direct	3.06	T8, 4ft, 32w, 3210K, CRI75	Furniture integrated	T8 and T12, 17~32w, 3148K, CRI85	No
3	Cubicles	Direct	2.55	T8, 4ft, 32w, 3207K, CRI76	Furniture integrated	T8, 17~25w, 3288K, CRI82	No
4	Cubicles	Direct	2.73	T8, 4ft, 32w, 3195K, CRI83	Furniture integrated	T8 and CFL, 32w, 3166K, CRI83	No
5	Cubicles	Direct	3.00	T8, 4ft, 32w, 3639K, CRI83	Furniture integrated	T8, 25w, 2718K, CRI84	No
6	Cubicles	Direct/ indirect	2.70	T8, 4ft, 32w, 3751K, CRI86	Furniture integrated	T12, 16w, 4153K, CRI67	Gold
7	Cubicles	Direct	2.64	T8, 4ft 32w, 3840K, CRI85	Furniture integrated	T8, 32w, 3655K, CRI82	No
8	Cubicles and open office	Direct/ indirect	2.44	T8, 4ft, 32 w, 3175K, CRI85	No task units for open office setup and furniture integrated units for cubicles	T8, 32w, 3913K, CRI63	Silver
9	Open office	Direct/ indirect	2.54	T8, 4f, 32w, 3834K, CRI85	Furniture mounted, height and position adjustable units	CFL, 13w, 4113K, CRI79	Platinum
10	Open office	Direct/ indirect	2.88	T8, 4f, 32w, 3303K, CRI82	No task lighting	No task lighting	Certified

APPENDIX S- LIGHTING RESULTS

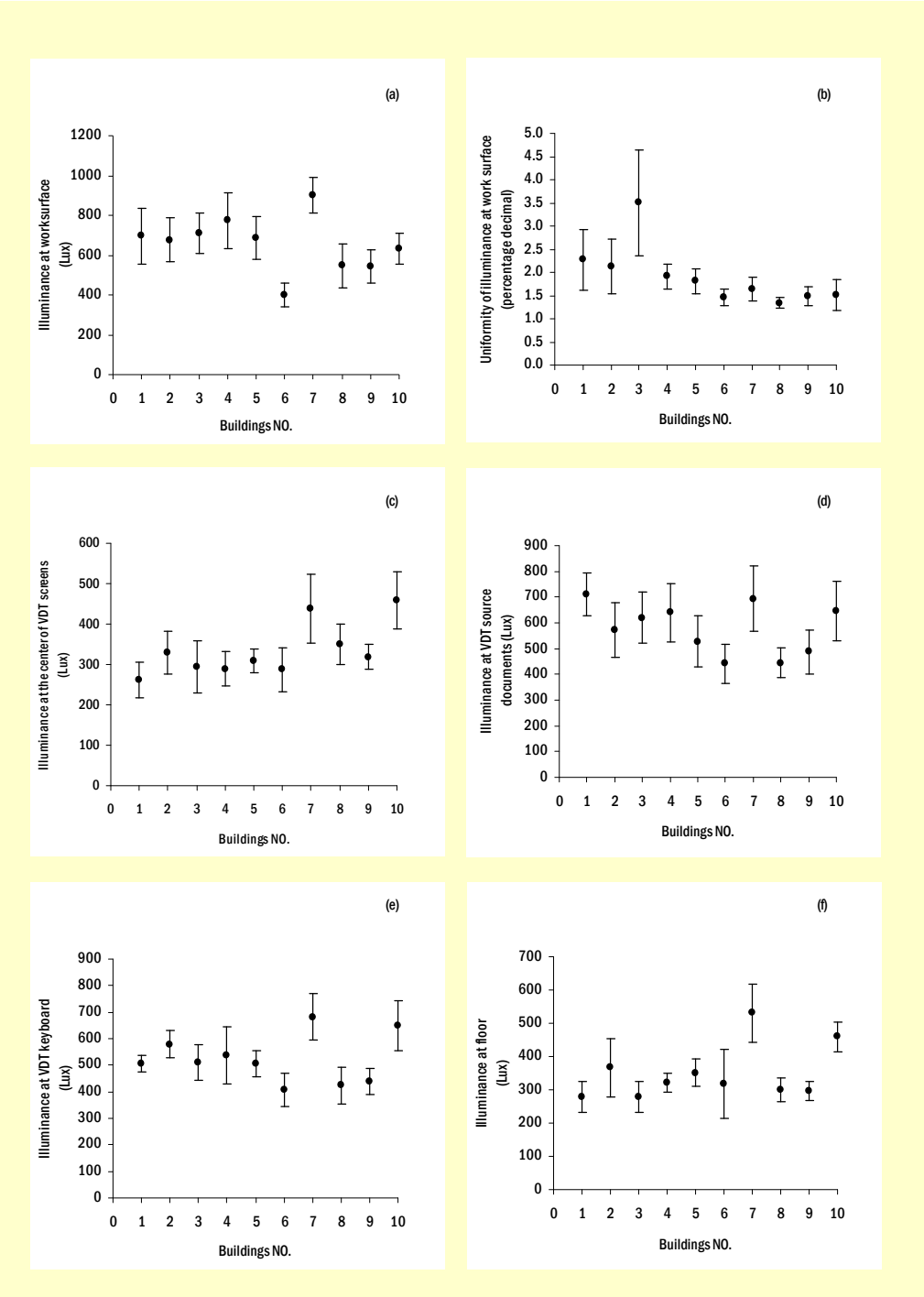


Figure S1. Illuminance-related measurements. a). Illuminance at work surface. b). Uniformity of illuminance at work surface. c) Illuminance at the center of VDTs. d) Illuminance at VDT source documents. e) Illuminance at VDT keyboard. f) Illuminance at floor.

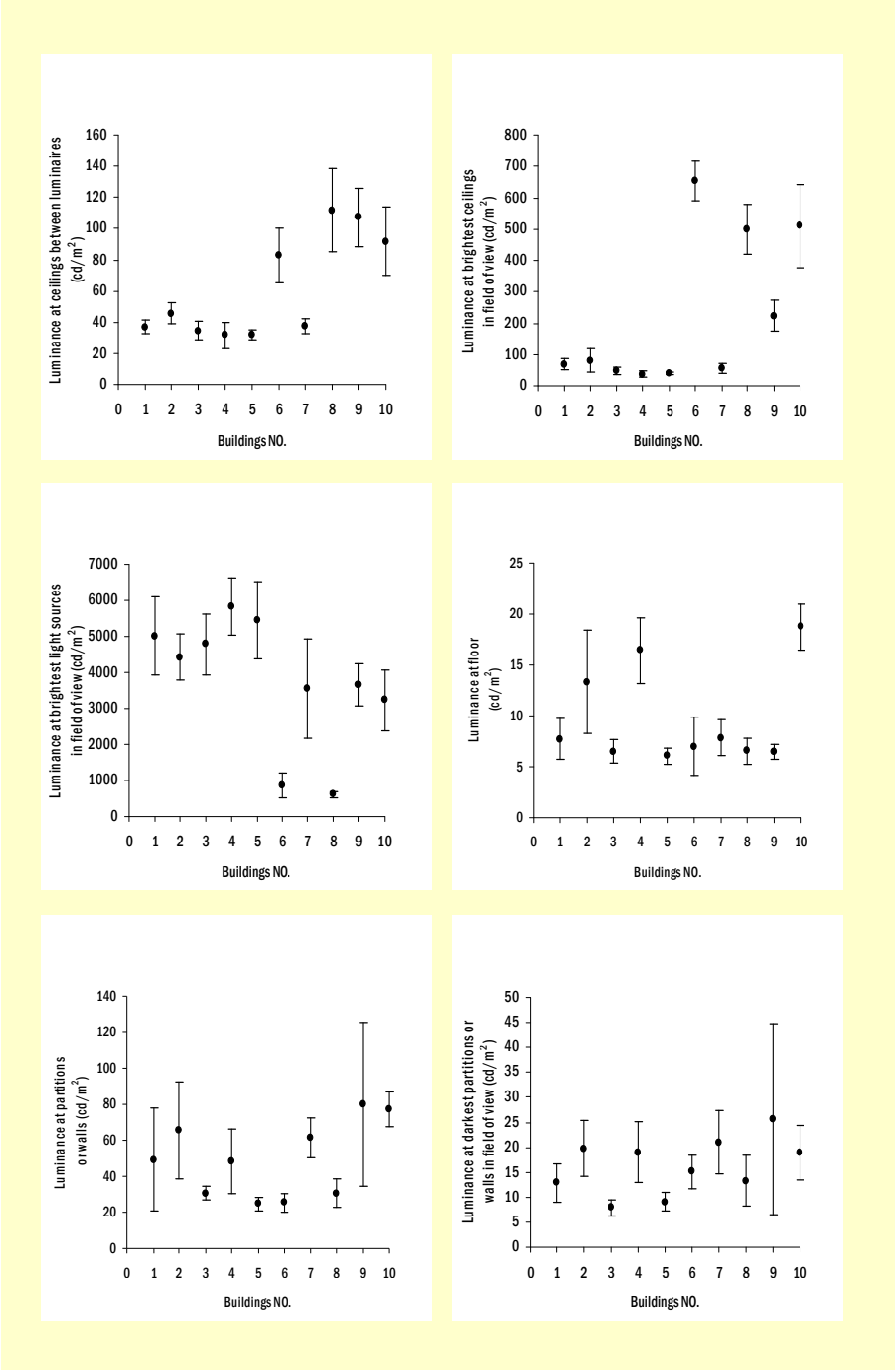

Luminance at ceilings between luminaires (cd/m²)
Buildings NO.
Luminance at brightest ceilings in field of view (cd/m²)
Buildings NO.
Luminance at brightest light sources in field of view (cd/m²)
Buildings NO.
Luminance at floor (cd/m²)
Buildings NO.
Luminance at partitions or walls (cd/m²)
Buildings NO.
Luminance at darkest partitions or walls in field of view (cd/m²)
Buildings NO.

Figure S2. Luminance-related measurements. a) Luminance at ceiling between luminaires; b) Luminance at brightest ceilings in field of view; c) Luminance at brightest light sources in field of view; d) Luminance at floor; e) Luminance at partitions or walls; and f) Luminance at darkest partitions or walls in field of view.

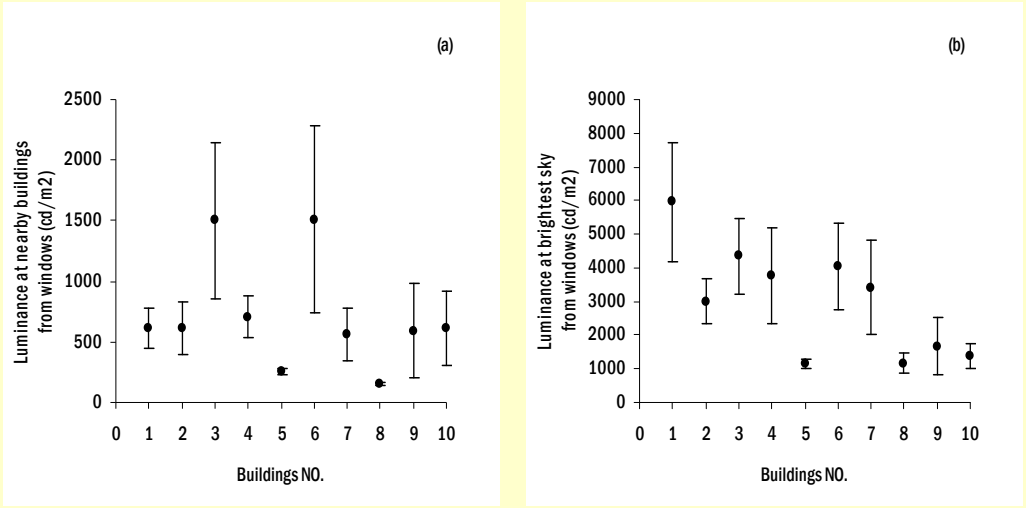


Figure S3. Luminance from windows. a) Luminance at nearby buildings from widows; and b). Luminance at brightest sky from windows.

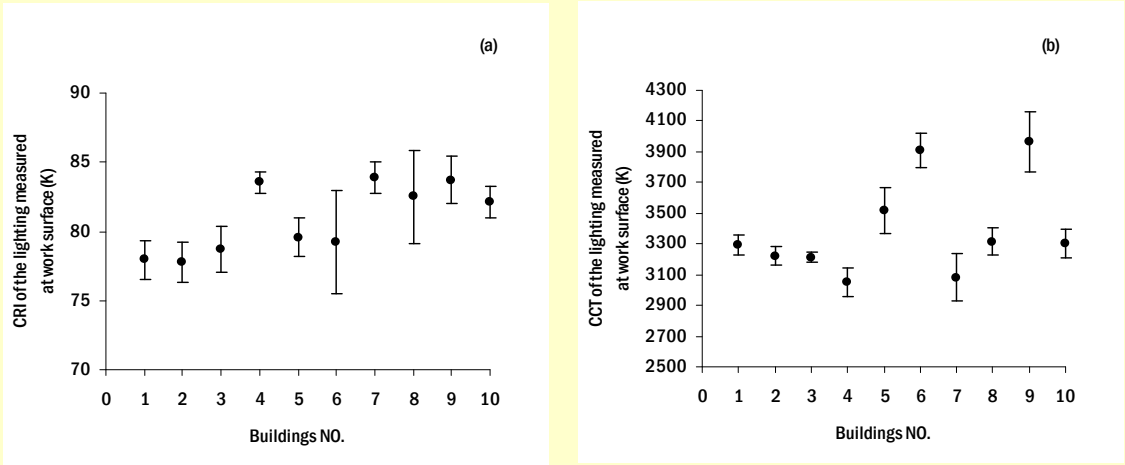


Figure S4. Color properties. a) CRI of the lighting measured at work surface; and b) CCT of the lighting measured at work surface.

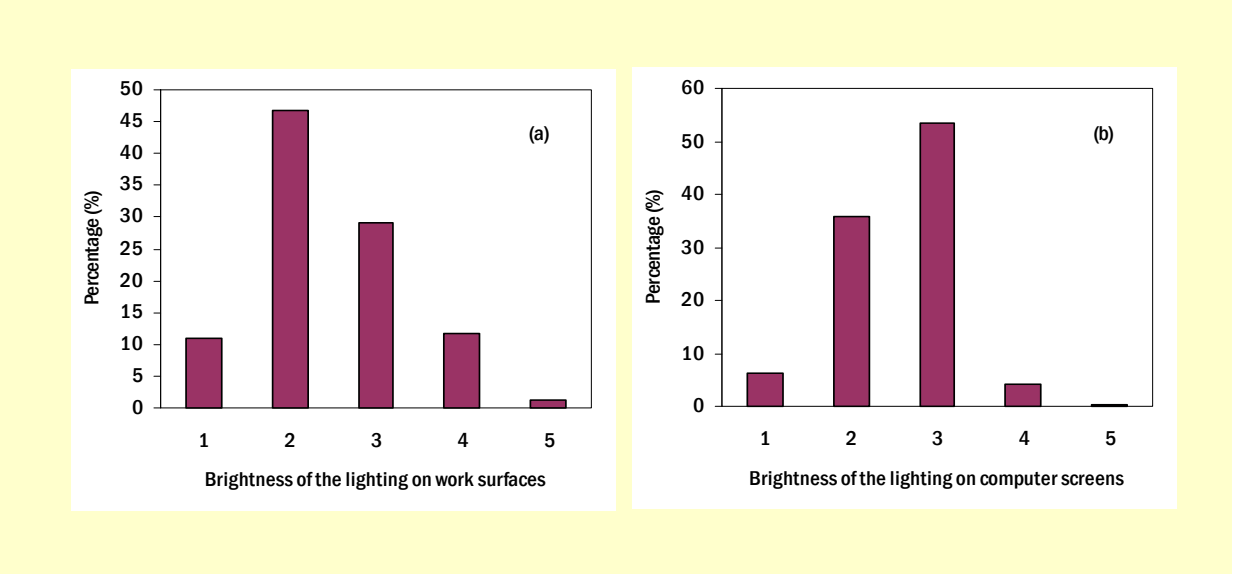


Figure S5. The perception questionnaire results regarding two brightness questions: (a) "The lighting on the desk or surface of my work station where I do most of my work is"; and (b) "The lighting on my computer screen is." The answers 1 to 5 represent very bright, somewhat or slightly bright, neither bright nor dim, somewhat bright or slightly dim and very dim or dark.

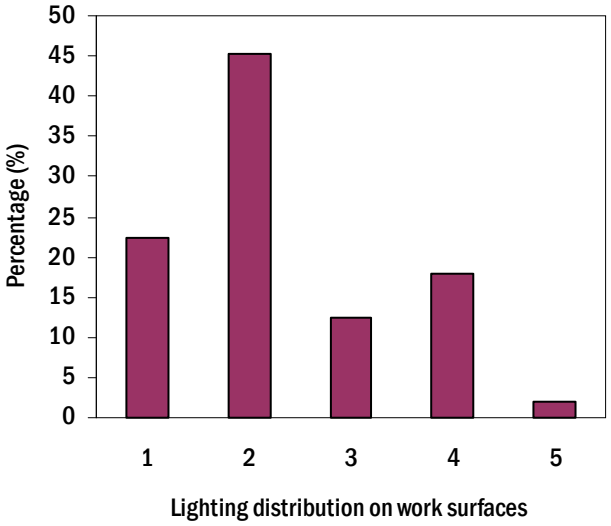


Figure S6. The perception questionnaire results regarding lighting distribution question, "The distribution of lighting across the surface of the area(s) where I read at my desk or workstation is," The answers 1 to 5 represent very uniform, somewhat uniform, neither uniform nor uneven, somewhat uneven, very uneven.

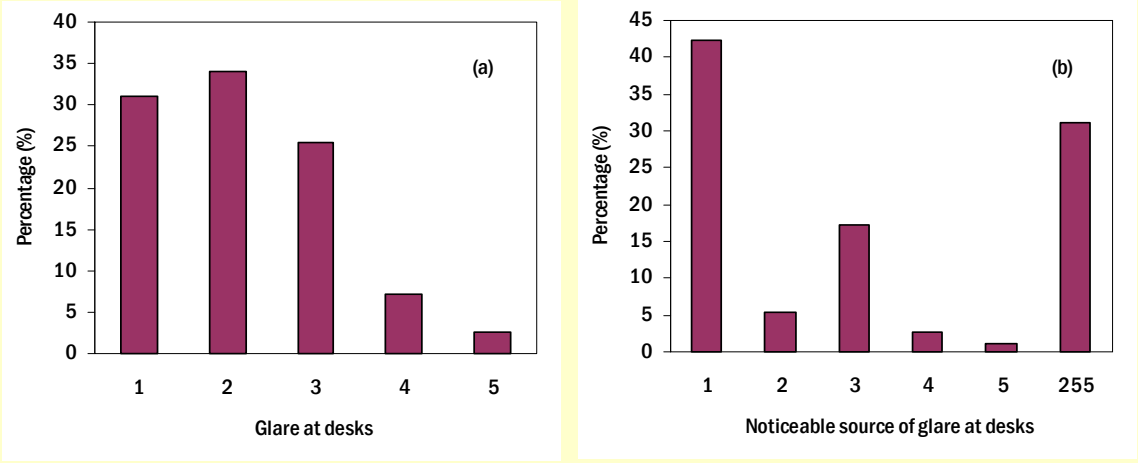


Figure S7. The perception questionnaire results regarding two direct glare questions: (a)"There is glare at my desk or workstation = Never (1), Occasionally (2), Some of the time (3), Most of the time (4), All of the time (5)"; (b)"The most noticeable source of glare at my desk or workstation comes from: Sunlight or daylight from windows(1), Task light(s) on my desk or from adjacent areas (2), Ceiling lights (3), Ceilings (4), Some other source(5), Don't have much glare(255).

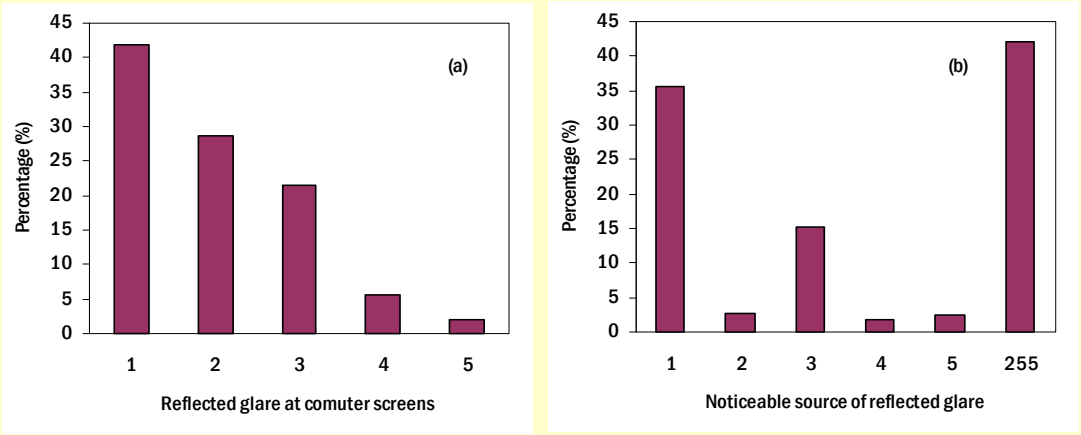


Figure S8. The perception questionnaire results regarding two reflected glare questions: (a)."There is reflected glare on my computer screen: Never (1), Occasionally (2), Some of the time (3), Most of the time (4), All of the time (5)"; (b)"The most noticeable source of reflected glare on my computer screen comes from: Sunlight or daylight from windows (1), Task light(s) on my desk or from adjacent areas (2), Ceiling lights (3), Ceilings (4), Some other source (5), Don't have much glare(255)."

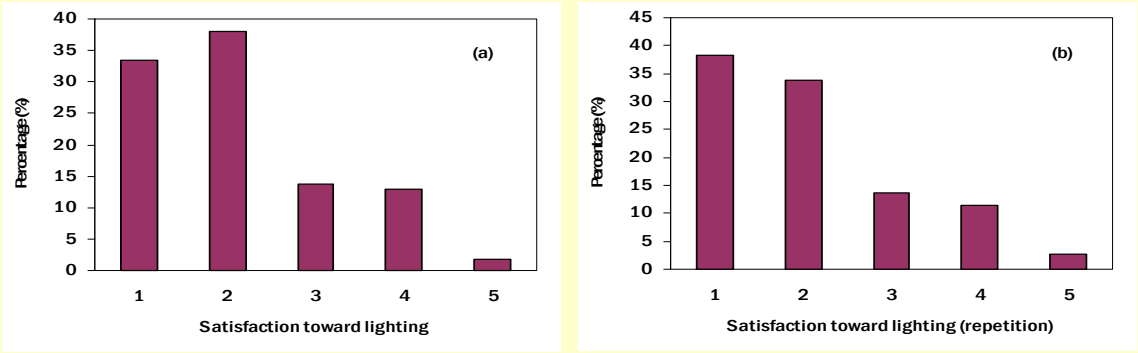


Figure S9. The perception questionnaire results regarding two satisfaction questions: (a)"in the past 4 weeks, I would rate my satisfaction with the lighting in my work area," and (b)"over the past 4 weeks, I have been satisfied with the lighting in my office." The answers 1 to 5 represent very satisfied, somewhat satisfied, neither satisfied nor dissatisfied, somewhat dissatisfied and strongly dissatisfied.

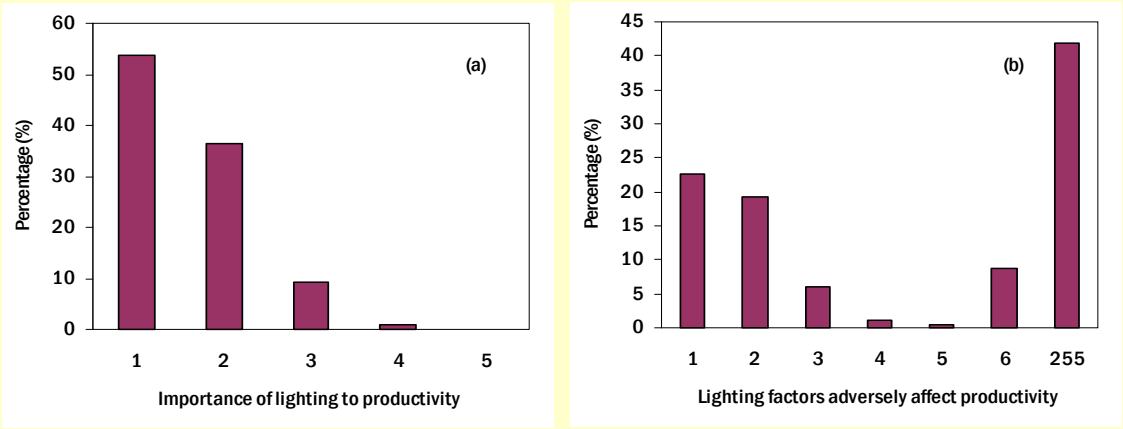


Figure S10. Four perception questionnaire results related to productivity. (a) "The quality of lighting in my work area is important to my ability to be productive. Strongly agree (1), Somewhat agree (2), Neither agree nor disagree (3), Somewhat disagree (4), Strongly disagree (5)." ; (b) "The lighting factor in my work area that most adversely affects my productivity is: The lighting is too bright or too dim (1), There is too much glare (2), The lights flicker (3), Irregular lighting patterns on walls (4), ceiling, and/or furniture or partitions (5), Colors are distorted (6). Did not answer the question (255)"; (c). "When there is too much glare on my desk surface or workstation, and/or on my computer screen, my productivity is adversely affected. Never (1), Occasionally (2), Some of the time (3), Most of the time (4), All of the time (5)"; (d) "When the lighting in my work area, on my desk surface or workstation, and/or on my computer screen is deficient or unacceptable during my work day, my productivity is adversely affected: Never (1), Occasionally (2), Some of the time (3), Most of the time (4), All of the time (5)."

APPENDIX T: BUILDING CHARACTERISTICS DATA

Table T1. Characteristics of Buildings 1-5.

Building ID	1	2	3	4	5
DOE Climate Zone	5a	5a	5a	3c	3c
Total count of occupants	65	400	600	50	300
Number of floors	1	1	2	1	2
Constructed after 1990	No	No	No	Yes	Yes
Construction Year	1988	1988	1987	2001	unknown
Oriented on a north/south axis	No	No	No	No	No
Major glass areas face: North	No	Yes	No	No	No
Major glass areas face: Northeast	No	No	No	No	No
Major glass areas face: East	No	Yes	Yes	Yes	Yes
Major glass areas face: Southeast	No	No	No	No	No
Major glass areas face: South	Yes	No	Yes	No	Yes
Major glass areas face: Southwest	No	No	No	No	No
Major glass areas face: West	Yes	No	No	No	Yes
Major glass areas face: Northwest	No	No	No	No	No
Major glass areas face: Equally Distributed	No	No	No	No	No
Window area ft2: North	Unknown	Unknown	Unknown	Unknown	Unknown
Window area ft2: South	Unknown	Unknown	Unknown	Unknown	Unknown
Window area ft2: East	Unknown	Unknown	Unknown	Unknown	Unknown
Window area ft2: West	Unknown	Unknown	Unknown	Unknown	Unknown
Construction Type	Insulated masonry-type panels	Insulated masonry-type panels	Insulated masonry-type panels	NIA	Heavy masonry material
Flat roof	Yes	Yes	Yes	NA/Unk	Yes
Light colored roof coating	Yes	NIA	Yes	No	Yes
Total roof area	Unknown	Unknown	Unknown	Unknown	Unknown
Roof R-value vs. bldg code	Met	Met	Unknown	Unknown	Unknown
Roof R-value	Unknown	Unknown	Unknown	Unknown	Unknown
E type insul glass	Yes	Yes	Yes	No	Yes
Window solar penetration reduction	Tinting	Tinting	Tinting	None	Tinting
Perimeter walls R-value vs. bldg code	Exceeded	Exceeded	Exceeded	Unknown	Unknown
Perimeter walls R-value	Unknown	Unknown	Unknown	Unknown	Unknown
Control system type	DDC	DDC	DDC	Unnown	Pneumatic
HVAC uses advanced EMCS	Yes	Yes	Yes	Yes	No

EMCS set-back type	Unknown	Turn off	Unknown	Unknown	Unknown
EMCS ctl on/off equip on 24/7 schedule	Yes	Yes	Yes	Unknown	Yes
EMCS used for electrical demand limiting	No	No	No	Unknown	No
Has programmable ES thermostats	Yes	Yes	Yes	Unknown	No
Type of thermostats	Unknown	Unknown	Unknown	Unknown	Unknown
Thermostats are tamperproof	No	No	No	Unknown	Unknown
[Typical] Type of work spaces	Other	Other	Other	Unknown	Multipurpose
Majority size of offices	Unknown	Unknown	Unknown	Unknown	Unknown
[Typical] Individual cube/office space/person	> 100 ft2	> 100 ft2	> 100 ft2	Unknown	50-100 ft2
Typical workspace shape	Rectangular	Rectangular	Rectangular	Unknown	Square
Type of walls	Permanent	Unknown	Unknown	Unknown	Partition/ Partial
Typical floor material	Carpet/Perm	Carpet/Perm	Carpet/Perm	Unknown	Carpet/Perm
[Typical] Ceiling heights	Less than 10 ft	Less than 10 ft	Less than 10 ft	Less than 10 ft	Less than 10 ft
Types of ceiling surfaces: Cement/structural	No	No	No	Unknown	No
Types of ceiling surfaces: Acoustic tile/hung	Yes	Yes	Yes	Unknown	Yes
Types of ceiling surfaces: Drywall/sheetrock	No	No	No	Unknown	No
Types of ceiling surfaces: Hard surface/cathedral	No	No	No	Unknown	No
Fixed outdoor sound sources: Air handlers	Yes	Yes	Yes	Unknown	No
Fixed outdoor sound sources: Motor/engines	No	No	No	Unknown	Yes
Fixed outdoor sound sources: Wind	No	No	No	Unknown	No
Fixed outdoor sound sources: Construction	No	No	No	Unknown	No
Fixed outdoor sound sources: Other	No	No	No	Unknown	No
Transportation sound sources: Highways	Yes	Yes	Yes	No	No
Transportation sound sources: Railways	No	No	No	No	No
Transportation sound sources: Airplanes	No	No	No	Yes	Yes
Transportation sound sources: Other	No	No	No	No	No

Inside sound sources not in work area: Pumps/motors on floor	No	No	No	Unknown	No
Inside sound sources not in work area: Activity above	No	No	No	Unknown	Yes
Inside sound sources not in wk area: Conversation in adjacent rooms	No	No	No	Unknown	No
Inside sound sources not in work area: Plumbing/air handlers	Yes	Yes	Yes	Unknown	No
Inside sound sources not in work area: Other	No	No	No	Unknown	No
Inside sound sources not in work area: Copiers/fax	Yes	Yes	Yes	Unknown	No
Inside sound sources not in work area: Computers	Yes	Yes	No	Unknown	No
Inside sound sources not in work area: Conversations	Yes	Yes	Yes	Unknown	Yes
Inside sound sources not in work area: Air conditioners	No	No	No	Unknown	No
Inside sound sources not in work area: Speech masking systems	No	No	No	Unknown	No
Work areas have background music	No	No	No	Unknown	No
Self cont roof top/mechanical equipment room units exist	Yes	Yes	Yes	Unknown	Yes
Air handling system	Variable Air Volume (VAV)	Variable Air Volume (VAV)	Variable Air Volume (VAV)	N/A	Variable Air Volume (VAV)
Air distribution system	Ceiling Air Dist (CAD)	Ceiling Air Dist (CAD)	Ceiling Air Dist (CAD)	Ceiling Air Dist (CAD)	Ceiling Air Dist (CAD)
Supply register type	Other	Other	Other	Unknown	Ceiling Diff
Return air type	Plenum	Plenum	Plenum	Ducted	Plenum
HVAC system type	Packaged roof-type unit(s)	Packaged roof-type unit(s)	Packaged roof-type unit(s)	Packaged roof-type unit(s)	Packaged roof-type unit(s)
Energy perf of chiller in kW/Ton	Unknown	Unknown	Unknown	Unknown	Unknown
Has thermal storage system	No	No	No	Unknown	No
Has self cont water src pumps in rooms	No	No	No	Unknown	No
Uses economizer cycle	Yes	Yes	Yes	Unknown	Yes
Filter replaced per maint schedule	Yes	Yes	Yes	Yes	Yes
Heating source	Furnace with std efficiency	Furnace with hi efficiency	Furnace with std efficiency	Unknown	Boiler with std efficiency
Light fixture type	Diffusers	Diffusers	Diffusers	Unknown	Parabolic
Lighting type [delivery]	Direct	Direct	Direct	Direct	Direct
Task lighting used	Yes	Yes	Yes	Yes	Yes
Gen purpose lighting type	Unknown	Unknown	Unknown	Unknown	Unknown

Lighting installed load w/ft2	Unknown	Unknown	Unknown	Unknown	Unknown
Lighting system voltage: 277 volts	Yes	Yes	Yes	Yes	Yes
Lighting system voltage: 208 volts	No	No	No	No	No
Lighting system voltage: 120 volts	No	No	No	No	No
Lighting control methods: Manual switching	Yes	Yes	Yes	Yes	Yes
Lighting control methods: Timing Device	Yes	Yes	Yes	Yes	Yes
Lighting control methods: Occupancy sensors	Yes	Yes	Yes	No	No
Lighting control methods: Photosensors	No	No	No	No	No
Lamp replacement	On Burnout	On Burnout	On Burnout	On Burnout	On Burnout
Group replacement interval (yrs between replacement)	N/A	N/A	N/A	N/A	N/A

Table T2. Characteristics of Buildings 6-10.

Building ID	6	7	8	9	10
DOE Climate Zone	6a	6a	4b	4a	6b
Total count of occupants	240	400	75	170	150
Number of floors	4	5	2	2	3
Constructed after 1990	Yes	Yes	Yes	Yes	Yes
Construction Year	2004	1997	2003	2004	2002
Oriented on a north/south axis	Unknown	Unknown	Unknown	Unknown	Unknown
Major glass areas face: North	No	No	No	No	Yes
Major glass areas face: Northeast	No	No	No	Yes	No
Major glass areas face: East	No	Yes	No	No	No
Major glass areas face: Southeast	No	No	No	No	No
Major glass areas face: South	No	No	No	Yes	Yes
Major glass areas face: Southwest	No	No	Yes	No	No
Major glass areas face: West	No	Yes	No	No	No
Major glass areas face: Northwest	No	No	Yes	No	No
Major glass areas face: Equally	Yes	No	No	No	No
Window area ft2: North	1122	3463	2518	Unknown	4243
Window area ft2: South	1090	3463	2342	Unknown	2724
Window area ft2: East	398	6080	1420	Unknown	1260
Window area ft2: West	1500	7601	1694	Unknown	1204
Construction Type	Heavy masonry material	Heavy masonry material	Heavy masonry material	Framed walls with exterior sheathing	Insulated masonry-type panels
Flat roof	Yes	Yes	Yes	Yes	Yes
Light colored roof coating	Yes	No	Yes	Yes	No
Total roof area	20398	30800	25620	124180	17334
Roof R-value vs. bldg code	Exceeded	Met	Exceeded	Exceeded	Met
Roof R-value	42	20	30	30	25
E type insulated glass	Yes	Yes	Yes	Yes	Yes
Window solar penetration reduction	Tinting	Shading	Tinting	Tinting	Tinting
Perimeter walls R-value vs. bldg code	Exceeded	Met	Exceeded	Exceeded	Met
Perimeter walls R-value	32	10	19	20	21
HVAC uses advanced EMCS	Yes	Yes	Yes	Yes	Yes
Control system type	Unknown	DDC	DDC	DDC	DDC
EMCS set-back type	Setback	Setback	Turn off	Setback	N/A
EMCS control on/off equip on 24/7 schedule	Yes	Yes	Yes	No	N/A

EMCS used for electric demand limiting	Yes	Yes	No	No	No
Has programmable ES thermostats	N/A	No	Yes	N/A	N/A
Type of thermostats	Unknown	Unknown	Unknown	Unknown	Unknown
Thermostats are tamperproof	No	Unknown	Yes	No	N/A
[Typical] Type of work space	Open	Other	Open	Open	Open
Majority size of work space	Unknown	Unknown	Unknown	Unknown	Unknown
[Typical] Individual cube/office space/person	50-100 ft2	> 100 ft2	50-100 ft2	Unknown	50-100 ft2
Typical shape	Square	Square	Rectangular	Square	Rectangular
Type of walls	Partition /Partial	Partition /Partial	Partition /Partial	Partition /Partial	Partition /Partial
[Typical floor material]	Carpet /Raised	Carpet/Perm	Carpet /Perm	Carpet /Raised	Carpet/Perm
[Typical] Ceiling heights	Less than 10 ft	Less than 10 ft	Less than 10 ft	10 ft or more	10 ft or more
Types of ceiling surfaces: Cement/structural	No	No	No	Yes	Yes
Types of ceiling surfaces: Acoustic tile/hung	Yes	Yes	Yes	No	No
Types of ceiling surfaces: Drywall/sheetrock	No	No	No	No	No
Types of ceiling surfaces: Hard surface/cathedral	No	No	No	No	No
Fixed outdoor sound sources: Air handlers	No	No	Yes	Yes	No
Fixed outdoor sound sources: Motor/engines	No	No	No	No	Yes
Fixed outdoor sound sources: Wind	No	Yes	No	Yes	Yes
Fixed outdoor sound sources: Construction	No	No	No	No	No
Fixed outdoor sound sources: Other	Yes	No	No	No	No
Transportation sound sources: Highways	No	Yes	Yes	Yes	No
Transportation sound sources: Railways	No	Yes	No	Yes	Yes
Transportation sound sources: Airplanes	No	No	No	No	No
Transportation sound sources: Other	Yes	No	No	No	Yes
Inside sound sources not in wk area: Pumps/motors on floor	No	No	No	No	Yes
Inside sound sources not in wk area: Activity above	No	No	No	No	Yes

Inside sound sources not in wk area: Conversation in adjacent rooms	Yes	Yes	Yes	Yes	No
Inside sound sources not in wk area: Plumbing/air handlers	No	No	No	No	No
Inside sound sources not in wk area: Other	No	No	No	No	No
Inside sound sources not in wk area: Copiers/fax	No	No	No	No	Yes
Inside sound sources not in wk area: Computers	No	No	No	No	No
Inside sound sources not in wk area: Conversations	No	Yes	Yes	Yes	Yes
Inside sound sources not in wk area: Air conditioners	No	Yes	No	Yes	Yes
Inside sound sources not in wk area: Speech masking systems	Yes	No	No	Yes	No
Work areas have background music	No	No	No	No	No
Self cont roof top/mechanical equipment room units exist	Yes	Yes	Yes	Yes	Yes
Air handling system	Variable Air Volume (VAV)	Variable Air Volume (VAV)	Variable Air Volume (VAV)	Constant Air Volume (CAV)	Variable Air Volume (VAV)
Air distribution system	Under Floor Air Dist (UFAD)	Ceiling Air Dist (CAD)	Ceiling Air Dist (CAD)	Under Floor Air Dist (UFAD)	Ceiling Air Dist (CAD)
Supply register type	Other	Ceiling Diff	Ceiling Diff	Other	Other
Return air type	Plenum	Plenum	Plenum	Unknown	Unknown
HVAC system type	Packaged roof-type unit(s)	Chilled-water	Chilled-water	Chilled-water	Packaged roof-type unit(s)
Energy perf of chiller in kW/Ton	Unknown	0.7-0.6	Unknown	0.8-0.7	Unknown
Has thermal storage system	No	No	No	No	No
Has self cont water src pumps in rooms	No	No	No	No	No
Uses economizer cycle	Yes	Yes	Yes	Yes	Yes
Filter replacement per maint schedule	Yes	Yes	Yes	Yes	Yes
Heating source	Unknown	Unknown	Furnace with hi efficiency	Boiler with hi efficiency	Boiler with hi efficiency
Light fixture type	Diffusers	Unknown	Unknown	Diffusers	Unknown
Lighting type [delivery]	Direct/Indirect	Direct	Direct/Indirect	Indirect	Direct/Indirect
Task lighting used	Yes	Yes	No	Yes	No
Gen purpose lighting type	Unknown	Unknown	Unknown	Unknown	Unknown
Lighting installed load w/ft2	Unknown	Unknown	Unknown	Unknown	Unknown
Lighting system voltage: 277 volts	Yes	Yes	Unknown	No	Yes

Lighting system voltage: 208 volts	No	No	Unknown	Yes	No
Lighting system voltage: 120 volts	No	No	Unknown	No	No
Lighting control methods: Manual switching	Yes	Yes	No	No	Yes
Lighting control methods: Timing Device	Yes	Yes	Yes	No	Yes
Lighting control methods: Occupancy sensors	No	Yes	Yes	Yes	Yes
Lighting control methods: Photosensors	Yes	No	Yes	Yes	No
Lamp replacement	On Burnout	On Burnout	On Burnout	On Group Replace	On Group Replace
Group replacement interval (yrs between replacement)	0	0	0	0	3

APPENDIX U: OCCUPANT PERCEPTION QUESTIONNAIRE.

This table list all the questions which were included in the computerized version. A number of questions are interdependent, i.e., a particular answer will trigger one or more additional questions. These interdependencies are not presented in this table.

Question	Response Choices				
Work Environment					
Over the past 4 weeks, the environment in my work area has been acceptable	All of the time	Most of the time	Some of the time	Rarely	Never
Over the past 4 weeks, I have noticed significant differences in the environment in my work area between mornings and afternoons	All of the time	Most of the time	Some of the time	Occasionally	Never
I perceive that my co-workers find the environment in their work area to be acceptable to them	All of the time	Most of the time	Some of the time	Rarely	Never
Compared with 6 months ago, the overall environment in my work area is	Much better	Somewhat better	No different	Somewhat worse	Much worse
Temperature					
On average, over the past 4 weeks, I would rate the temperature in my work area as acceptable	All of the time	Most of the time	Some of the time	Occasionally	Never
In general, I'm most comfortable when the temperature in my work area is	Very cool	Somewhat or slightly cool	Neither too cool nor too warm	Somewhat or slightly warm	Very warm
Throughout the course of an entire work day, the temperature in my work area fluctuates (I.e., goes from warm to cool, and/or cool to warm)	All of the time	Most of the time	Some of the time	Rarely	Never
Throughout the mornings, the temperature in my work area is usually	Very cool	Somewhat cool	Neither too cool nor too warm	Somewhat warm	Very warm
Throughout the afternoons the temperature in my work area is usually	Very cool	Somewhat cool	Neither too cool nor too warm	Somewhat warm	Very warm
The temperature in my work area is too cool for at least some part of the work day	Every work day	Most work days	Some work days	Occasionally	Never
When the temperature in my work area is too cool I adjust the thermostat	All of the time	Most of the time	Some of the time	Occasionally	Never
When the temperature in my work area is too cool I use a personal space heater	All of the time	Most of the time	Some of the time	Occasionally	Never

Question	Response Choices				
When the temperature in my work area is too cool I wear warmer clothing and/or put on a sweater/jacket	All of the time	Most of the time	Some of the time	Occasionally	Never
When the temperature in my work area is too cool I report it to management or facilities personnel	All of the time	Most of the time	Some of the time	Occasionally	Never
When the temperature in my work area is too cool I temporarily leave my work area to go to a warmer area	All of the time	Most of the time	Some of the time	Occasionally	Never
When the temperature in my work area is too cool I open or close a door	All of the time	Most of the time	Some of the time	Occasionally	Never
When the temperature in my work area is too cool I block or unblock air supply registers close to my work area	All of the time	Most of the time	Some of the time	Occasionally	Never
When the temperature in my work area feels too cool, I feel it most in my	Head/face	Feet	Hands	Chest/back	All over my body
When the temperature in my work area feels too cool, my productivity is adversely affected	All of the time	Most of the time	Some of the time	Occasionally	Never
The temperature in my work area is too warm during my work day for at least some part of the work day	Every work day	Most work days	Some work days	Occasionally	Never
When the temperature in my work area is too warm I adjust the thermostat	All of the time	Most of the time	Some of the time	Occasionally	Never
When the temperature in my work area is too warm I use a personal fan	All of the time	Most of the time	Some of the time	Occasionally	Never
When the temperature in my work area is too warm, I wear lighter clothing or remove clothing	All of the time	Most of the time	Some of the time	Occasionally	Never
When the temperature in my work area is too warm, I open or close a door	All of the time	Most of the time	Some of the time	Occasionally	Never
When the temperature in my work area is too warm, I report it to management or facilities personnel	All of the time	Most of the time	Some of the time	Occasionally	Never
When the temperature in my work area is too warm, I leave my work area to go to a more comfortable area	All of the time	Most of the time	Some of the time	Occasionally	Never
When the temperature in my work area feels too warm, I feel it most in my	Head/face	Feet	Hands	Chest/back	All over my body
When the temperature in my work area feels too warm, my productivity	All of the time	Most of the time	Some of the time	Occasionally	Never

Question	Response Choices				
is adversely affected					
Humidity					
On average, over the past 4 weeks, I would rate the humidity/dryness of the air in my work area as acceptable	All of the time	Most of the time	Some of the time	Occasionally	Never
In general, I'm most comfortable when the air in my work area is	Very humid	Somewhat or slightly humid	Neither too humid nor too dry	Somewhat or slightly dry	Very dry
Throughout the course of an entire work day, the air in my work area fluctuates between humid and dry (i.e., goes from humid to dry, and/or from dry to humid)	All of the time	Most of the time	Some of the time	Rarely	Never
Throughout the mornings, the air in my work area is usually	Very humid	Somewhat or slightly humid	Neither too humid nor too dry	Somewhat or slightly dry	Very dry
Throughout the afternoons the air in my work area is usually	Very humid	Somewhat or slightly humid	Neither too humid nor too dry	Somewhat or slightly dry	Very dry
The air in my work area is too dry during my work day for at least some part of the work day	Every work day	Most work days	Some work days	Occasionally	Never
When the air in my work area is too dry during my work day, I use a personal humidifier	Every work day	Most work days	Some work days	Occasionally	Never
When the air in my work area is too dry I adjust the thermostat	All of the time	Most of the time	Some of the time	Occasionally	Never
When the air in my work area is too dry, I use a moisturizer cream or lotion on my skin	All of the time	Most of the time	Some of the time	Occasionally	Never
When the air in my work area is too dry, I put lubricant drops in my eyes	All of the time	Most of the time	Some of the time	Occasionally	Never
When the air in my work area is too dry, I report it to management or facilities personnel	All of the time	Most of the time	Some of the time	Occasionally	Never
When the air in my work area is too dry, I open or close a door	All of the time	Most of the time	Some of the time	Occasionally	Never
When the air in my work area is too dry, I temporarily leave my work area to go to a more comfortable area	All of the time	Most of the time	Some of the time	Occasionally	Never
When the air in my work area feels too dry my productivity is adversely affected	All of the time	Most of the time	Some of the time	Occasionally	Never
The air in my work area is too humid during my work day for at least some part of the work day	Every work day	Most work days	Some work days	Occasionally	Never
When the air in my work area is too	All of the time	Most of the time	Some of the	Occasionally	Never

Question	Response Choices				
humid, I adjust the thermostat			time		
When the air in my work area is too humid, I use a personal fan	Every work day	Most work days	Some work days	Occasionally	Never
When the air in my work area is too humid, I put on lighter clothing or remove clothing	All of the time	Most of the time	Some of the time	Occasionally	Never
When the air in my work area is too humid, I open or close a door	All of the time	Most of the time	Some of the time	Occasionally	Never
When the air in my work area is too humid, I report it to management or facilities personnel	All of the time	Most of the time	Some of the time	Occasionally	Never
When the air in my work area is too humid, I temporarily leave my work area to go to a more comfortable area	All of the time	Most of the time	Some of the time	Occasionally	Never
When the air in my work area is too humid I report it to management or facilities personnel	All of the time	Most of the time	Some of the time	Occasionally	Never
When my work area feels too humid, my productivity is adversely affected	All of the time	Most of the time	Some of the time	Occasionally	Never
Draft					
On average, over the past 4 weeks, I would rate the air in my work area as acceptable in terms of feeling a draft	All of the time	Most of the time	Some of the time	Occasionally	Never
In general, I'm most comfortable when the air in my work area is	Very drafty	Somewhat or slightly drafty	Neither too drafty nor too stagnant	Somewhat or slightly stagnant	Very stagnant
Throughout the course of an entire work day, the air in my work area fluctuates from drafty to not drafty and vice versa	All of the time	Most of the time	Some of the time	Rarely	Never
Throughout the mornings, the air in my work area is usually	Very drafty	Somewhat or slightly drafty	Neither too drafty nor too stagnant	Somewhat or slightly stagnant	Very stagnant
Throughout the afternoons the air in my work area is usually	Very drafty	Somewhat or slightly drafty	Neither too drafty nor too stagnant	Somewhat stagnant	Very stagnant
The air in my work area is too drafty during my work day for at least some part of the work day	Every work day	Most work days	Some work days	Occasionally	Never
When I feel a draft in my work area during my work day, I block the diffuser	Every work day	Most work days	Some work days	Occasionally	Never
When I feel a draft in my work area during my work day, I open/close a door	All of the time	Most of the time	Some of the time	Occasionally	Never

Question	Response Choices				
When I feel a draft in my work area during my work day, I report it to management or facilities personnel	All of the time	Most of the time	Some of the time	Occasionally	Never
When I feel a draft in my work area during my work day, I temporarily leave my work area to go to a more comfortable area	All of the time	Most of the time	Some of the time	Occasionally	Never
When I feel a draft in my work area during my work day, my productivity is adversely affected	All of the time	Most of the time	Some of the time	Occasionally	Never
Stagnant / Stuffy					
On average, over the past 4 weeks, the air in my work area as acceptable in terms of being stuffy or stagnant	All of the time	Most of the time	Some of the time	Occasionally	Never
In general, I'm most comfortable when the air in my work area is	Very fresh	Somewhat or slightly fresh	Neither too fresh nor too stuffy	Somewhat or slightly stuffy	Very stuffy
Throughout the course of an entire work day, the air in my work area fluctuates between being fresh and being stuffy	All of the time	Most of the time	Some of the time	Rarely	Never
The air in my work area is too stuffy during my work day for at least some part of the work day	Every work day	Most work days	Some work days	Occasionally	Never
When I feel the air in my work area is stuffy during my work day, I adjust the thermostat	Every work day	Most work days	Some work days	Occasionally	Never
When I feel the air in my work area is stuffy during my work day, I use a personal fan	All of the time	Most of the time	Some of the time	Occasionally	Never
When I feel the air in my work area is stuffy during my work day, I open/close a door	All of the time	Most of the time	Some of the time	Occasionally	Never
When I feel the air in my work area is stuffy during my work day, I report it to management or facilities personnel	All of the time	Most of the time	Some of the time	Occasionally	Never
When I feel the air in my work area is stuffy during my work day, I temporarily leave my work area to go to a more comfortable area	All of the time	Most of the time	Some of the time	Occasionally	Never
When I feel the air in my work area is stuffy during my work day, my productivity is adversely affected	All of the time	Most of the time	Some of the time	Occasionally	Never
Odor					

Question	Response Choices				
On average, over the past 4 weeks, the air in my work area as acceptable in terms of unpleasant odors	All of the time	Most of the time	Some of the time	Occasionally	Never
The odor that is **most noticeable** to me in my work area smells like	Cleaning chemicals	Musty/moldy	Perfume or cologne	Body odor (human)	Sewage or garbage
I smell this most noticeable odor in my work area	All of the time	Most of the time	Some of the time	Occasionally or intermittently	Never
This most noticeable odor in my work area is present	Only in my work area	In my work area and in some nearby work areas or offices	In my work area and in scattered other locations elsewhere in the building	In my work area and throughout my entire floor or office, but not elsewhere in the building	In my work area and throughout the entire building
This most noticeable odor tends to occur during	Mornings	Afternoons	Mornings and Afternoons	Unpredictably during the work day	Not applicable
When I smell this most noticeable odor during my work day, I spray the air in my work area with an air freshener or similar odor-masking product	Every work day	Most work days	Some work days	Occasionally	Never
When I smell this most noticeable odor during my work day, I use a personal fan	All of the time	Most of the time	Some of the time	Occasionally	Never
When I smell this most noticeable odor during my work day, I open/close a door	All of the time	Most of the time	Some of the time	Occasionally	Never
When I smell this most noticeable odor during my work day, I report it to management or facilities personnel	All of the time	Most of the time	Some of the time	Occasionally	Never
When I smell this most noticeable odor during my work day, I temporarily leave my work area to go to a more comfortable area	All of the time	Most of the time	Some of the time	Occasionally	Never
When I smell this most noticeable odor during my work day, my productivity is adversely affected	All of the time	Most of the time	Some of the time	Occasionally	Never

Question	Response Choices				
Lighting					
On average, over the past 4 weeks, I would rate my satisfaction with the lighting in my work as	Very satisfied	Somewhat satisfied	Neither satisfied nor dissatisfied	Somewhat dissatisfied	Very dissatisfied
The quality of lighting in my work area is important to my ability to be productive	Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
If I had the ability the adjust the lighting in my work area, I would do so	All of the time	Most of the time	Some of the time	Occasionally	Never
In general, I'm most comfortable when the lighting in my work area is	Very bright	Somewhat or slightly bright	Neither too bright nor too dim	Somewhat or slightly dim	Very dim or dark
Throughout the course of an entire work day, the brightness of the lighting in my work area fluctuates (I.e., goes from bright to dim, and/or dim to bright)	All of the time	Most of the time	Some of the time	Rarely	Never
Throughout the mornings, the lighting in my work area is usually	Very bright	Somewhat or slightly bright	Neither too bright nor too dim	Somewhat or slightly dim	Very dim or dark
Throughout the afternoons the lighting in my work area is usually	Very bright	Somewhat or slightly bright	Neither too bright nor too dim	Somewhat or slightly dim	Very dim or dark
In general, the lighting on my **desk surface or work station** where I do most of my work is	Very bright	Somewhat or slightly bright	Neither too bright nor too dim	Somewhat or slightly dim	Very dim or dark
In general, the lighting on my **computer screen** is	Very bright	Somewhat or slightly bright	Neither too bright nor too dim	Somewhat or slightly dim	Very dim or dark
The distribution of lighting across the surface of the area(s) **where I read** at my desk or work station is	Very uniform (even)	Somewhat uniform (even)	Neither uniform nor uneven	Somewhat uneven	Very uneven
The distribution of lighting across the surface of my **computer screen** is	Very uniform (even)	Somewhat uniform (even)	Neither uniform nor uneven	Somewhat uneven	Very uneven
I prefer to have natural light from outdoors come into my office or work area	Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
There is **glare** (harsh uncomfortably bright light) at my desk or work station	All of the time	Most of the time	Some of the time	Occasionally	Never
The **most noticeable** source of **glare** at my desk or work station comes from	Sunlight or daylight from windows	Task light(s) on my desk or from adjacent areas	Ceiling lights	Ceilings	NA

Question	Response Choices				
There is reflected glare (uncomfortably bright reflection from one or more light sources) on my **computer screen**	All of the time	Most of the time	Some of the time	Occasionally	Never
The **most noticeable** source of **reflected glare** on my computer screen comes from	Sunlight from windows	Task light(s) on my desk or from adjacent areas	Ceiling lights	Ceilings	NA
When there is too much glare on my desk surface or work station, and/or on my computer screen, my productivity is adversely affected	All of the time	Most of the time	Some of the time	Occasionally	Never
The amount of daylight or sunlight that enters my work area is	Excessive	More than sufficient	Neither excessive nor insufficient	Somewhat or slightly insufficient	Very insufficient
When the amount of natural sunlight or daylight that enters my office or work area is excessive, I close the drapes or close the blinds to those windows	All of the time	Most of the time	Some of the time	Occasionally	Never
When the amount of natural sunlight or daylight that enters my office or work area is insufficient, I open the drapes or open the blinds to those windows	All of the time	Most of the time	Some of the time	Occasionally	Never
There is **flickering** of the lights in my work area	All of the time	Most of the time	Some of the time	Occasionally	Never
The lights in my work area make a **humming or buzzing** sound	All of the time	Most of the time	Some of the time	Occasionally	Never
There are distracting, irregular lighting patterns on the walls, ceiling, and/or furniture in my work area	All of the time	Most of the time	Some of the time	Occasionally	Never
The color of people's faces and objects in my work area appears natural	Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
The color of the lighting in my office or work area is	Too cool (has a blue hue)	Somewhat cool	Neither too cool nor too warm	Somewhat warm (has a yellow hue)	Too warm
Shadows are created in my work area because the light source is blocked	All of the time	Most of the time	Some of the time	Occasionally	Never
The lighting factor in my work area that most adversely affects my productivity is	The lighting is too bright or too dim	There is too much glare	The lights flicker	Irregular lighting patterns on walls, ceiling, and/or furniture or partitions	Colors are distorted

Question	Response Choices				
When the lighting in my work area is deficient or unacceptable, I adjust the lighting for the entire work area	All of the time	Most of the time	Some of the time	Occasionally	Never
When the lighting in my work area is deficient or unacceptable, I adjust the window blinds or shades	All of the time	Most of the time	Some of the time	Occasionally	Never
When the lighting in my work area is deficient or unacceptable, I use a desk lamp to augment or improve the lighting on my desk or work station	All of the time	Most of the time	Some of the time	Occasionally	Never
When the lighting in my work area is deficient or unacceptable, I report it to management or facilities personnel	All of the time	Most of the time	Some of the time	Occasionally	Never
When the lighting in my work area is deficient or unacceptable, I temporarily leave my work area to go to a more comfortable area	All of the time	Most of the time	Some of the time	Occasionally	Never
When the lighting in my work area is deficient or unacceptable, I complain about it to co-workers but don't do anything	All of the time	Most of the time	Some of the time	Occasionally	Never
When the lighting in my work area, on my desk surface or work station, and/or on my computer screen is deficient or unacceptable during my work day, my productivity is adversely affected	All of the time	Most of the time	Some of the time	Occasionally	Never
Sound					
On average, over the past 4 weeks, I would rate the sound or noise environment in my work area as acceptable	All of the time	Most of the time	Some of the time	Occasionally	Never
In general, I'm most comfortable when the sound or noise in my work area is	Very quiet	Somewhat or slightly quiet	Neither too quiet nor too noisy loud	Somewhat or slightly noisy loud	Very noisy loud
Throughout the course of an entire work day, the sound or noise in my work area fluctuates (I.e., goes from loud to quiet, and/or quiet to loud)	All of the time	Most of the time	Some of the time	Rarely	Never
I **hear** sound(s) from outside the building (airplanes, traffic, trains, construction, mechanical equipment, sirens, etc..) in my work area	All of the time	Most of the time	Some of the time	Rarely	Never
When I hear sound(s) from outside the building (airplanes, traffic, trains, construction, mechanical equipment, sirens, etc..)in my work area, I am **annoyed/distracted**	All of the time	Most of the time	Some of the time	Rarely	Never

Question	Response Choices				
When I hear sound(s) from outside the building (airplanes, traffic, trains, construction, mechanical equipment, sirens, etc..) in my work area, my **productivity is adversely affected**	All of the time	Most of the time	Some of the time	Rarely	Never
When I hear sound(s) from outside the building (airplanes, traffic, trains, construction, mechanical equipment, sirens, etc..) in my work area, it typically distracts me or adversely affects my productivity **within**	A few seconds	About 30 seconds	About 2 minutes	About 15 minutes	About 30 minutes or more
When I hear sound(s) from outside the building (airplanes, traffic, trains, construction, mechanical equipment, sirens, etc..), it typically distracts me or affects my productivity **for as long as**	A few seconds	About 30 seconds	About 2 minutes	About 15 minutes	About 30 minutes or more
When I hear sound(s) from outside the building (airplanes, traffic, trains, construction, mechanical equipment, sirens, etc..), it annoy(s)/distract(s) me and/or adversely affect(s) my productivity **because**	Sound is too loud	Sound is intermittent and/or unpredictable	Sound continuously fluctuates (increases and/or decreases) in loudness over time	One tone dominates the sound	The sound or conversation is understandable
I **hear** sound(s) from telephone/speakerphone conversations that carry into my work area	All of the time	Most of the time	Some of the time	Rarely	Never
When I hear sound(s) from telephone/speakerphone conversations that carry into my work area, I am **annoyed/distracted**	All of the time	Most of the time	Some of the time	Rarely	Never
When I hear sound(s) from telephone/speakerphone conversations that carry into my work area, my **productivity is adversely affected**	All of the time	Most of the time	Some of the time	Rarely	Never
When I hear sound(s) from telephone/speakerphone conversations that carry into my work area, it typically distracts me or adversely affects my productivity **within**	A few seconds	About 30 seconds	About 2 minutes	About 15 minutes	About 30 minutes or more
When I hear sound(s) from telephone/speakerphone conversations that carry into my work area, it typically distracts me or affects my productivity **for as long as**	A few seconds	About 30 seconds	About 2 minutes	About 15 minutes	About 30 minutes or more

Question	Response Choices				
When I hear sound(s) from telephone/speakerphone conversations that carry into my work area, it annoys/distracts me and/or adversely affects my productivity **because**	Sound is too loud	Sound is intermittent and/or unpredictable	Sound continuously fluctuates (increases and/or decreases) in loudness over time	One tone dominates the sound	The sound or conversation is understandable
When I hear sound(s) from telephone or speakerphone conversations that carry into my work area, I do not have enough privacy to have a conversation with another person or a private telephone conversation	All of the time	Most of the time	Some of the time	Rarely	Never
When I hear sound(s) from telephone or speakerphone conversations that annoys/distracts me and/or affects my work productivity, I ask the person(s) who is/are making the sound/noise to **be quiet or move**	All of the time	Most of the time	Some of the time	Rarely	Never
I **hear** sound(s) from person-to-person conversations in or near my work area	All of the time	Most of the time	Some of the time	Rarely	Never
When I hear sound(s) from person-to-person conversations in or near my work area, I am **annoyed/distracted**	All of the time	Most of the time	Some of the time	Rarely	Never
When I hear sound(s) from person-to-person conversations in or near my work area, my **productivity is adversely affected**	All of the time	Most of the time	Some of the time	Rarely	Never
When I hear sound(s) from person-to-person conversations in or near my work area, it typically distracts me or adversely affects my productivity **within**	A few seconds	About 30 seconds	About 2 minutes	About 15 minutes	About 30 minutes or more
When I hear sound(s) from person-to-person conversations in or near my work area, it typically distracts me or affects my productivity for **as long as**	A few seconds	About 30 seconds	About 2 minutes	About 15 minutes	About 30 minutes or more
When I hear sound(s) from person-to-person conversations in or near my work area, it annoys/distracts me and/or adversely affects my productivity **because**	Sound is too loud	Sound is intermittent and/or unpredictable	Sound continuously fluctuates (increases and/or decreases) in loudness over time	One tone dominates the sound	The sound or conversation is understandable

Question	Response Choices				
When I hear sound(s) from person-to-person conversations in or near my work area, I do not have enough privacy to have a conversation with another person or a private telephone conversation	All of the time	Most of the time	Some of the time	Rarely	Never
When I hear sound(s) or noise created by person-to-person conversations that annoys/distracts me and/or affects my work productivity, I ask the person(s) who is/are making the sound/noise to **be quiet or move**	All of the time	Most of the time	Some of the time	Rarely	Never
I **hear** sound(s) from piped-in music or masking sound in or near my work area	All of the time	Most of the time	Some of the time	Rarely	Never
When I hear sound(s) from piped-in music or masking sound in or near my work area, I am **annoyed/distracted**	All of the time	Most of the time	Some of the time	Rarely	Never
When I hear sound(s) from piped-in music or masking sound in or near my work area, my **productivity is adversely affected**	All of the time	Most of the time	Some of the time	Rarely	Never
When I hear sound(s) from piped-in music or masking sound in or near my work area, it typically distracts me or adversely affects my productivity **within**	A few seconds	About 30 seconds	About 2 minutes	About 15 minutes	About 30 minutes or more
When I hear sound(s) from piped-in music or masking sound in or near my work area, it typically distracts me or affects my productivity for **as long as**	A few seconds	About 30 seconds	About 2 minutes	About 15 minutes	About 30 minutes or more
When I hear sound(s) from piped-in music or masking sound in or near my work area, it annoys/distracts me and/or adversely affects my productivity **because**	Sound is too loud	Sound is intermittent and/or unpredictable	Sound continuously fluctuates (increases and/or decreases) in loudness over time	One tone dominates the sound	The sound or conversation is understandable
I **hear** sound(s) from paging or announcement system in or near my work area	All of the time	Most of the time	Some of the time	Rarely	Never
When I hear sound(s) from paging or announcement system in or near my work area, I am **annoyed/distracted**	All of the time	Most of the time	Some of the time	Rarely	Never
When I hear sound(s) from paging or announcement system in or near my work area, my **productivity is**	All of the time	Most of the time	Some of the time	Rarely	Never

Question	Response Choices				
adversely affected					
When I hear sound(s) from paging or announcement system in or near my work area, it typically distracts me or adversely affects my productivity **within**	A few seconds	About 30 seconds	About 2 minutes	About 15 minutes	About 30 minutes or more
When I hear sound(s) from paging or announcement system in or near my work area, it typically distracts me or affects my productivity for **as long as**	A few seconds	About 30 seconds	About 2 minutes	About 15 minutes	About 30 minutes or more
When I hear sound(s) from paging or announcement system in or near my work area, it annoys/distracts me and/or adversely affects my productivity **because**	Sound is too loud	Sound is intermittent and/or unpredictable	Sound continuously fluctuates (increases and/or decreases) in loudness over time	One tone dominates the sound	The sound or conversation is understandable
I **hear** sound(s) from nearby office equipment (copy machine, printer, fax) in my work area	All of the time	Most of the time	Some of the time	Rarely	Never
When I hear sound(s) from nearby office equipment (copy machine, printer, fax) in my work area, I am **annoyed/distracted**	All of the time	Most of the time	Some of the time	Rarely	Never
When I hear sound(s) from nearby office equipment (copy machine, printer, fax) in my work area, my **productivity is adversely affected**	All of the time	Most of the time	Some of the time	Rarely	Never
When I hear sound(s) from nearby office equipment (copy machine, printer, fax) in my work area, it typically distracts me or adversely affects my productivity **within**	A few seconds	About 30 seconds	About 2 minutes	About 15 minutes	About 30 minutes or more
When I hear sound(s) from nearby office equipment (copy machine, printer, fax) in my work area, it typically distracts me or affects my productivity for **as long as**	A few seconds	About 30 seconds	About 2 minutes	About 15 minutes	About 30 minutes or more
When I hear sound(s) from nearby office equipment (copy machine, printer, fax) in my work area, it annoys/distracts me and/or adversely affects my productivity **because**	Sound is too loud	Sound is intermittent and/or unpredictable	Sound continuously fluctuates (increases and/or decreases) in loudness over time	One tone dominates the sound	The sound or conversation is understandable

Question	Response Choices				
I **hear** sound(s) from building mechanical equipment (air-conditioning compressors, pumps) in my work area	All of the time	Most of the time	Some of the time	Rarely	Never
When I hear sound(s) from building mechanical equipment (air-conditioning compressors, pumps) in my work area, I am **annoyed/distracted**	All of the time	Most of the time	Some of the time	Rarely	Never
When I hear sound(s) from building mechanical equipment (air-conditioning compressors, pumps) in my work area, my **productivity is adversely affected**	All of the time	Most of the time	Some of the time	Rarely	Never
When I hear sound(s) from building mechanical equipment (air-conditioning compressors, pumps) in my work area, it typically distracts me or adversely affects my productivity **within**	A few seconds	About 30 seconds	About 2 minutes	About 15 minutes	About 30 minutes or more
When I hear sound(s) from building mechanical equipment (air-conditioning compressors, pumps) in my work area, it typically distracts me or affects my productivity for **as long as**	A few seconds	About 30 seconds	About 2 minutes	About 15 minutes	About 30 minutes or more
When I hear sound(s) from building mechanical equipment (air-conditioning compressors, pumps) in my work area, it annoys/distracts me and/or adversely affects my productivity **because**	Sound is too loud	Sound is intermittent and/or unpredictable	Sound continuously fluctuates (increases and/or decreases) in loudness over time	One tone dominates the sound	The sound or conversation is understandable
When I hear sounds from building mechanical equipment (air-conditioning compressors, pumps), it seems to **come mainly from**	Nearby wall(s)	The ceiling	The floor	Through the window	Through a doorway
When I hear sounds from building mechanical equipment (air-conditioning compressors, pumps), the **predominant distinguishing characteristic** that I notice is a	Rumbling sound	Roaring sound	Hum or whistle	Hiss	Noticeable rattles
I **hear** sound(s) from Air-supply or return-air diffusers (located on ceiling, wall, and/or floor) in my work area	All of the time	Most of the time	Some of the time	Rarely	Never
When I hear sound(s) from Air-supply or return-air diffusers (located on ceiling, wall, and/or floor) in my	All of the time	Most of the time	Some of the time	Rarely	Never

Question	Response Choices				
work area, I am **annoyed/distracted**					
When I hear sound(s) from air-supply or return-air diffusers (located on ceiling, wall, and/or floor)in my work area, my **productivity is adversely affected**	All of the time	Most of the time	Some of the time	Rarely	Never
When I hear sound(s) from air-supply or return-air diffusers (located on ceiling, wall, and/or floor) in my work area, it typically distracts me or adversely affects my productivity **within**	A few seconds	About 30 seconds	About 2 minutes	About 15 minutes	About 30 minutes or more
When I hear sound(s) from air-supply or return-air diffusers (located on ceiling, wall, and/or floor) in my work area, it typically distracts me or affects my productivity for **as long as**	A few seconds	About 30 seconds	About 2 minutes	About 15 minutes	About 30 minutes or more
When I hear sound(s) from air-supply or return-air diffusers (located on ceiling, wall, and/or floor)) in my work area, it annoys/distracts me and/or adversely affects my productivity **because**	Sound is too loud	Sound is intermittent and/or unpredictable	Sound continuously fluctuates (increases and/or decreases) in loudness over time	One tone dominates the sound	The sound or conversation is understandable
When I hear sound coming from air-supply and/or return air diffusers, it seems to **come mainly from**	Nearby wall(s)	Ceiling	Floor	Can't tell	Not applicable
When I hear sound coming from air-supply and/or return air diffusers, the **predominant distinguishing characteristic** that I notice is a	Rumbling sound	Roaring sound	Hum or whistle	Hiss	Noticeable rattles
When I hear sound coming from air-supply and/or return air diffusers, some or all of it **sounds like mechanical equipment**	All of the time	Most of the time	Some of the time	Rarely	Never
When I hear sound coming from air-supply and/or return air diffusers, some or all of it **sounds like voices**	All of the time	Most of the time	Some of the time	Rarely	Never
I **hear** sound(s) from sounds or noises created by building occupants (music, cell phones, body sounds) in my work area	All of the time	Most of the time	Some of the time	Rarely	Never
When I hear sound(s) from sounds or noises created by building occupants (music, cell phones, body sounds) in my work area, I am **annoyed/distracted**	All of the time	Most of the time	Some of the time	Rarely	Never

Question	Response Choices				
When I hear sound(s) from sounds or noises created by building occupants (music, cell phones, body sounds) in my work area, my **productivity is adversely affected**	All of the time	Most of the time	Some of the time	Rarely	Never
When I hear sound(s) from sounds or noises created by building occupants (music, cell phones, body sounds) in my work area, it typically distracts me or adversely affects my productivity **within**	A few seconds	About 30 seconds	About 2 minutes	About 15 minutes	About 30 minutes or more
When I hear sound(s) sounds or noises created by building occupants (music, cell phones, body sounds) in my work area, it typically distracts me or affects my productivity for **as long as**	A few seconds	About 30 seconds	About 2 minutes	About 15 minutes	About 30 minutes or mor
When I hear sound(s) from sounds or noises created by building occupants (music, cell phones, body sounds)in my work area, it annoys/distracts me and/or adversely affects my productivity **because**	Sound is too loud	Sound is intermittent and/or unpredictable	Sound continuously fluctuates (increases and/or decreases) in loudness over time	One tone dominates the sound	The sound or conversation is understandable
When I hear sound(s) or noise created by building occupants (music, cell phones, body sounds) that annoys/distracts me and/or affects my work productivity, I ask the person(s) who is/are making the sound/noise to **be quiet or move**	All of the time	Most of the time	Some of the time	Rarely	Never
On average, over the past 4 weeks, I would rate the privacy in my work area as acceptable	All of the time	Most of the time	Some of the time	Rarely	Never
When I hear any sound(s) in my work area that annoy/distract me and/or affect my work productivity, I do not have enough privacy to have a conversation with another person(s) in my work area	All of the time	Most of the time	Some of the time	Rarely	Never
When I hear any sound(s) in my work area that annoy/distract me and/or affect my work productivity, I do not have enough privacy to have a telephone conversation in my work area	All of the time	Most of the time	Some of the time	Rarely	Never
When I do not have acceptable privacy in my work area, I move to a more private area to have private conversations with others	All of the time	Most of the time	Some of the time	Rarely	Never

Question	Response Choices				
When I do not have acceptable privacy in my work area, I move to a more private area to have telephone conversations	All of the time	Most of the time	Some of the time	Rarely	Never
When I do not have acceptable privacy in my work area, I postpone private conversations with others to times when people in or near my work area are not present	All of the time	Most of the time	Some of the time	Rarely	Never
When I do not have acceptable privacy in my work area, I postpone telephone conversations to times when people in or near my work area are not present	All of the time	Most of the time	Some of the time	Rarely	Never

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